PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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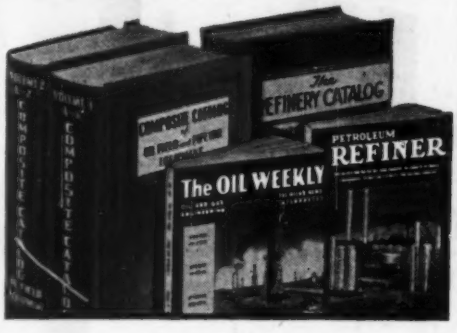

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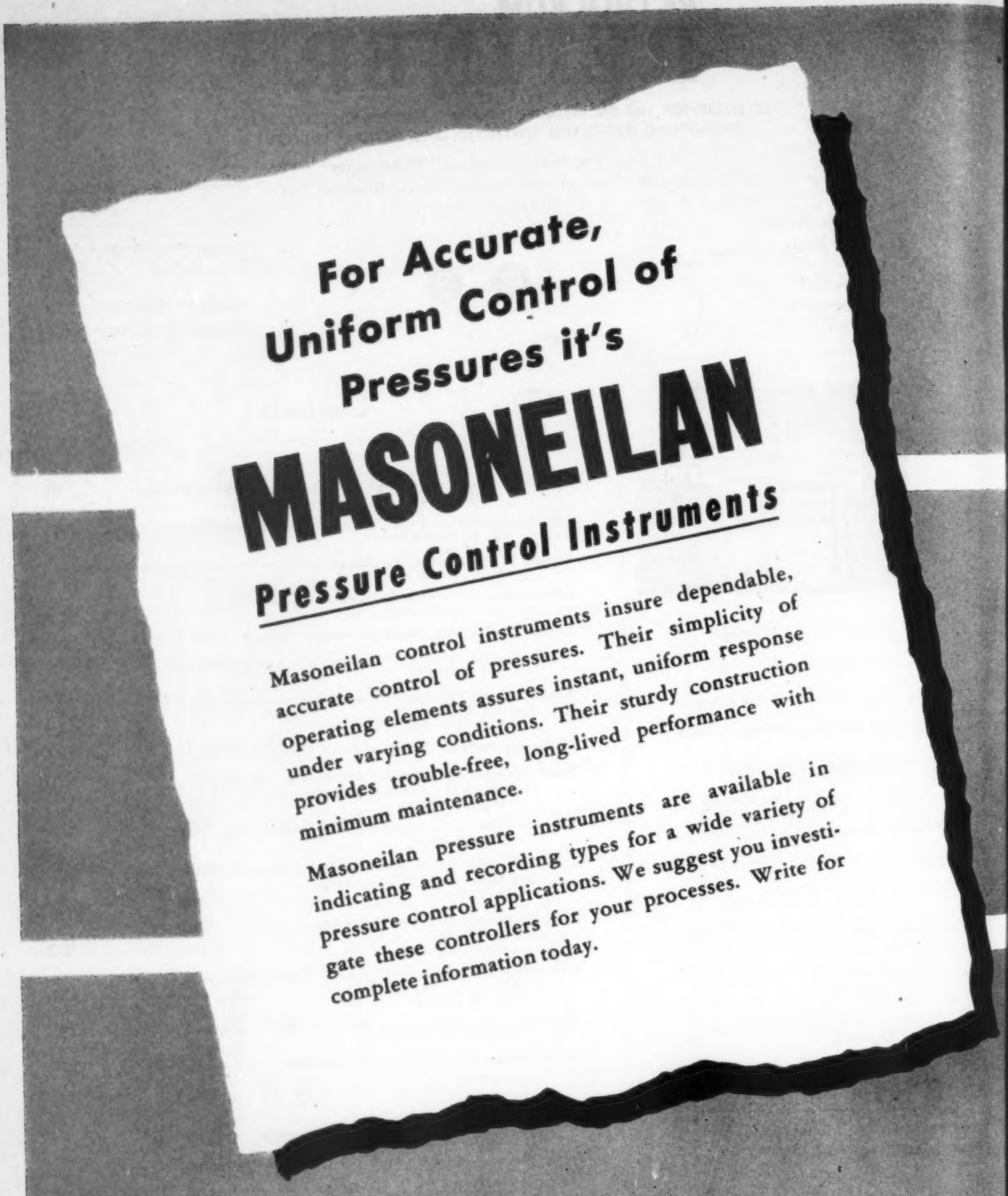
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THE LOOK BOX

AS AN organization the National Petroleum Council has a list of officials and an ear turned in the direction of the Department of the Interior. It will give consideration only to questions that come from the Secretary of the Interior or from its director of its oil and gas division.

Burned Fingers

Even with a work sheet out of the Department of the Interior, however, the council reserves the right to reject from that list. This attitude evidently is based on memory of what happened prior to the war period. In that period through the Petroleum Administration for War the industry took over what come from its director. Questions were not in order.

But ten years before that another cooperative program came out of Washington—NRA. It met a sad fate before the old Supreme Court, which measured the legislation by the constitution and came up with a negative reply. Elements of official Washington were so displeased that industry was urged to continue under NRA codes on a voluntary basis.

The oil industry continued some of those practices, with the result that several of its outstanding corporation and personalities shortly were hailed into court at Madison, Wisconsin, under charges of violating the law. And it so happened that men who approved of adhering to NRA standard on a voluntary basis did not come forward to testify for the men and corporations of the industry.

MEN who draw their livelihood from refining should give some attention to a peculiar condition in the industry. Never before has there been so much new construction prospect. It is doubtful if ever before there was ever such delay in construction. It will have a serious effect on the source of livlihood in years to come.

Men and Processes

Before the Petroleum Division of the American Chemical Society in Chicago last month, Bruce K. Brown said that as much as 75 percent of the crude oil charged into a plant could be converted into gasoline, given the proper equipment. Whether that is desirable is not the question. The industry is bent on that incline. More units and more efficient units are demanded.

Here is another incident, one of the thousands that are a part of the delay. Recently a salesman had a customer in need of alloy tubing. In time he found the tubing, two thousand miles distant. The transaction moved properly up to the point of shipping. Then a strike of truck drivers put an end to the whole transaction. The refining company has abandoned the alteration for the reason that material is difficult to buy.

Refining and allied processing make up a big industry. It promises to grow even more, for the processes are at hand by which 75 percent of crude oil can be converted into gasoline or converted into scores of other finished merchandise, especially chemicals. But the difficulty of building is a handicap that is discouraging. Men simply lose

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heart when repeated effort fails to provide what industry has a right to expect.

If processing is curtailed for lack of materials, it will be the refinery worker who suffers most. Instead of more jobs in the highest paid of the processing industries, men are going to find themselves competing more and more with instruments.

Automatic control is something for the worker to weigh and consider. His one assurance of conquering it is that more units and more processes will be added, thus calling for more men despite the efficiency of instruments.

Work Shortage

THERE is error in the accepted condition so frequently described as "shortage of materials." Not enough finished materials are at hand for the construction job that demands completion in the United States. Only a part of the job belongs to petroleum.

But the United States has ample materials, raw materials. It has ample manufacturing facilities more than it previously has had. In fact agencies of government are striving to dispose of what is termed "excess facilities."

The shortage that exists in the United States today has been imposed by working methods, or lack of working methods. Given ample raw materials and an excess of plant capacity, men simply are not producing what this country needs.

This country needs a plan of work, one directed by each man who wants to work. Gigantic plans prepared in high places simply do not get raw materials converted into useful things.

Atomic Power

THAT THE COST of atomic power for some purposes is within reason was indicated by Dr. Charles A. Thomas before the meeting of the American Chemical Society in Chicago in September. The vice president of Monsanto Chemical Company and project director of its Clinton Laboratories at Oak Ridge gave details from an atomic power cost survey prepared for the United Nations Atomic Energy Committee.

This survey showed that an atomic power plant for 75,000 KW could be built in the United States for $25,000,000 on which these costs were calculated:

"On the assumption that the plant would operate at 100 percent capacity and that interest charges on the investment would be 3 percent, the plant could produce power at approximately 0.8 cents per kilowat hour. This figure has been computed by different groups of engineers working independently."

Under similar conditions a coal-burning plant would cost $10,000,000 and the delivered cost of coal at $7.00 per ton would leave, "the cost of producing power in this plant at approximately 0.65 cents per kilowat hour. Equality of operating costs between the coal-power plants and nuclear-power plants would be reached if the Coal cost were $10 per ton."

After discussing the rising trend of coal prices and the prospect of reducing atomic power plants, he concluded:

"It would appear that the cost of nuclear power may decrease and the cost of coal power will increase. The results proves that the development of nuclear power is attractive to certain industries."

Of interest to the petroleum industry is the fact that atomic power will have influence on oil consumption as well as on coal consumption.

Such Faith

THOSE visionaries who insist upon further appeasement of Russia might have their mental cataracts pierced by considering world-petroleum affairs. Russia alone holds its statistics of oil secret. Since Russia alone had knowledge of her own resources, she alone has knowledge of world petroleum resources.

This is a situation of vital significance, since it has bearing on such vitally important matters as control of atomic energy and world peace. In a situation like this, it requires vast optimism to hope for an effective international control of atomic energy, such as the Baruch proposal to the United Nations. Since Russia so successfully withholds facts concerning its oil resources, it is not difficult to surmise what its attitude would be toward submitting to the international controls and inspections that would be required by an atomic authority. It is a bold proposal, if not visionary, to expect this of a country which holds even oil statistics in strict secrecy, although having access to similar facts for other nations.

If knowledge of atomic energy sources today were on the same basis as oil, Russia alone would have complete information and the rest of the world could only conjecture regarding the resources within the Iron Curtain.

Leg Work

ALTHOUGH it has not become an organization of unlimited activity, the National Petroleum Council has learned that 31 federal agencies have some authority of petroleum affairs. This was one announcement to come out of the October meeting of the organization that will function under directions of the Department of the Interior.

Even getting around to all points of possible authority will call for fast stepping in Washington.

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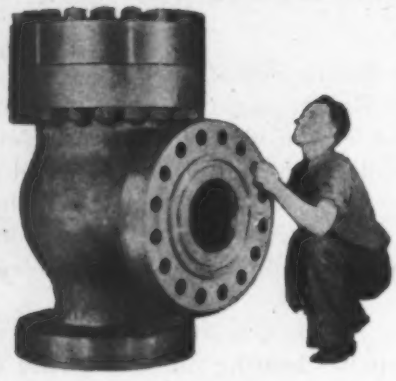

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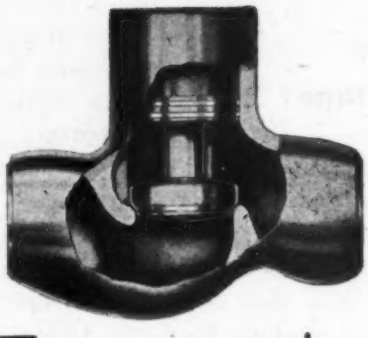

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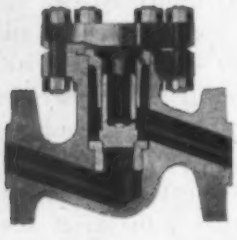

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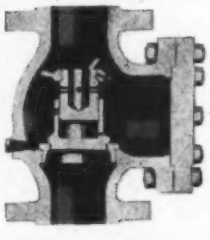

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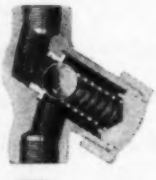

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Automatic Control Of A Fluid Catalytic Cracking Unit

M. MacDONALD, Chief Process Control Engineer
The M. W. Kellogg Company

AUTOMATIC CONTROL of continuous processing has been developed to a very high degree within the past decade. One of the most significant advances has been made in the field of petroleum refining. Process-control engineers charged with the responsibility of solving the multitude of problems that have arisen while the art of petroleum refining was being brought to its present high state have had the closest cooperation with the engineers of the instrument manufacturers. This close cooperation enabled the process-control engineers and the manufacturers' instrument engineers to readily solve the complex control problems that faced them when World War II brought the demand for aviation gasoline far in excess of the capacity of then existing equipment.

When the demand for new refining capacity became so urgent, The M. W. Kellogg Company introduced Fluid Catalytic Cracking which, was so different from conventional refining methods and so dependent upon automatic control for its success that control problems became of paramount importance. A simplified flow diagram of the process without controls or instrumentation is shown in Figure 1.

The Process

The oil stock to be processed is pumped through a series of heat exchangers, for economy, and then through a preheater furnace to bring it to a temperature that will insure its vaporization when contacted by hot regenerated catalyst at the injection point. Vaporization is necessary because the finely-divided catalyst is not moved through the process at any point by purely mechanical means such as pumps, elevators or conveyors but is carried by means of compressible vapors. These vapors may be oil, air, steam, or gas. The charge-stock-oil vapors act as the carrier for the regenerated catalyst, moving it to the reactor where the cracking reaction takes place at about 950° F. The products of the reaction are carried to the top of the reactor where they pass through cyclone separators which remove most of the fine catalyst particles from the vapors and return them to the reactor through a tailpipe. The vapor is then passed to a fractionating tower where it is separated into the desired product components.

Spent catalyst is continuously withdrawn from the reactor to a spent-catalyst stripper where the absorbed and entrained vapors are recovered and returned to the process. The stripped catalyst falls into a standpipe and is conveyed to the regenerator by means of air introduced at a point below the standpipe slide valve. In the regenerator, the oxygen in the air serves to reactivate the catalyst by burning off its carbon deposit. The regenerator temperature is approximately 1050° F.

Catalyst is withdrawn continuously from the regenerator through a standpipe and slide-valve arrangement, similar to that of the reactor, to the oil-injection point where the circulating catalyst cycle is completed. The cycle is repeated continuously.

The products of combustion from the catalyst regeneration phase of the process pass through cyclone separators, in the top of the regenerator and the separated catalyst is dropped back into the regenerator bed through a tailpipe.

A second standpipe and slide-valve arrangement removes catalyst from the regenerator bed. Air introduced below this slide valve carries the hot catalyst through a cooler back to the regenerator. This circuit is called the recycle catalyst cooler circuit and in large units it is important in the control of the process.

Catalyst fines carried from the regenerator through the flue-gas cooler are separated from the flue gas by a Cottrell precipitator which collects them in a hopper. The catalyst thus recovered is dropped through a standpipe and slide valve to a carrier air stream which returns it to the regenerator.

Catalyst fines that are carried from the reactor cyclones to the fractinator tower are settled out with the oil in the bottom of the tower. The catalyst-bearing oil (or slurry) is separated in a settling compartment in the base of the fractionator from which the thickened slurry may be pumped back to the fresh-feed line and thus returned to the reactor.

Pressure Differential Instruments

One of the first things determined from pilot-plant operation was that the process could be controlled successfully by means of pressure differential, and that pressure-differential instruments could be used to measure the level of the catalyst in the vessels, just as readily as they could be used for similar service in liquids. It also became apparent that pressure differential in the carrier lines was a function of flow.

One of the first problems to be solved in the application of these instruments was the method of keeping the pressure taps free of catalyst, as the instruments would very quickly become unserviceable due to plugging of the taps by deposits of fine catalyst. This trouble was overcome by the addition of a complete bleed air system which allowed air to flow into each tap at a predetermined rate that would keep the tap free of catalyst. This rate was fixed by means of a restriction orifice installed in the line before the tee through which bleed air was fed to the instrument tap, as illustrated in Figure 2.

The next problem to be solved was how to overcome the erosion of thermowells and slide valves due

to the sand blasting effect of the catalyst. Mild steel angle guards were installed in the line of flow upstream to the thermowells in the flow lines and minimized the erosive effects. As the continuous on-stream time of these units became one year and more, it became desirable to dsign and install thermowells that could be removed and replaced safely while the unit was in full operation. These have been proved successful. Erosion of slide valves presented a more serious problem which has been solved by the use of two slide valves in series, one being run wide open and put in service only when the other became unserviceable, and increasing the service life of each by redesign of the standpipes to materially reduce the velocity of catalyst flow through the valves.

Since the slide valves are positioned by the output air of an automatic controller, it was necessary to arrange the instrument-controlled air piping so that automatic control could be shifted from one to the other without any upset in the process. A manual air loading station is arranged to position the valve not under automatic control. The piping was arranged so that a movement of one four-way valve would transpose the controls, as shown in Figure 3.

The overall automatic control design of this process required the control of six systems interlocked with or related to the main oil system. Design of the control of each has been made with consideration of its effect upon the others. The six are: the catalyst, carrier air, aeration air, slurry, waste heat steam, and bleed air systems.

The oil-charge stream of the plant (Figure 1) is controlled at a constant rate of flow of 17,000 barrels per day. The temperature of this stream is held constant at the ouelet of the preheater furnace at 750° F. by an electronic temperature recorder-controller having a range of 500-1000° F. This controller sets the index of a flow recorder-controller which controls the rate of flow of fuel gas to the furnace at 40,000 cubic feet per hour. The temperature of the reaction is held at 910° F. by an electronic temperature recording controller having a range of 600-1100° F. The reactor pressure is maintained by a pressure controller holding a constant pressure on the suction dry drum of the compressors which remove the noncondensed vapors from the fractionator overhead.

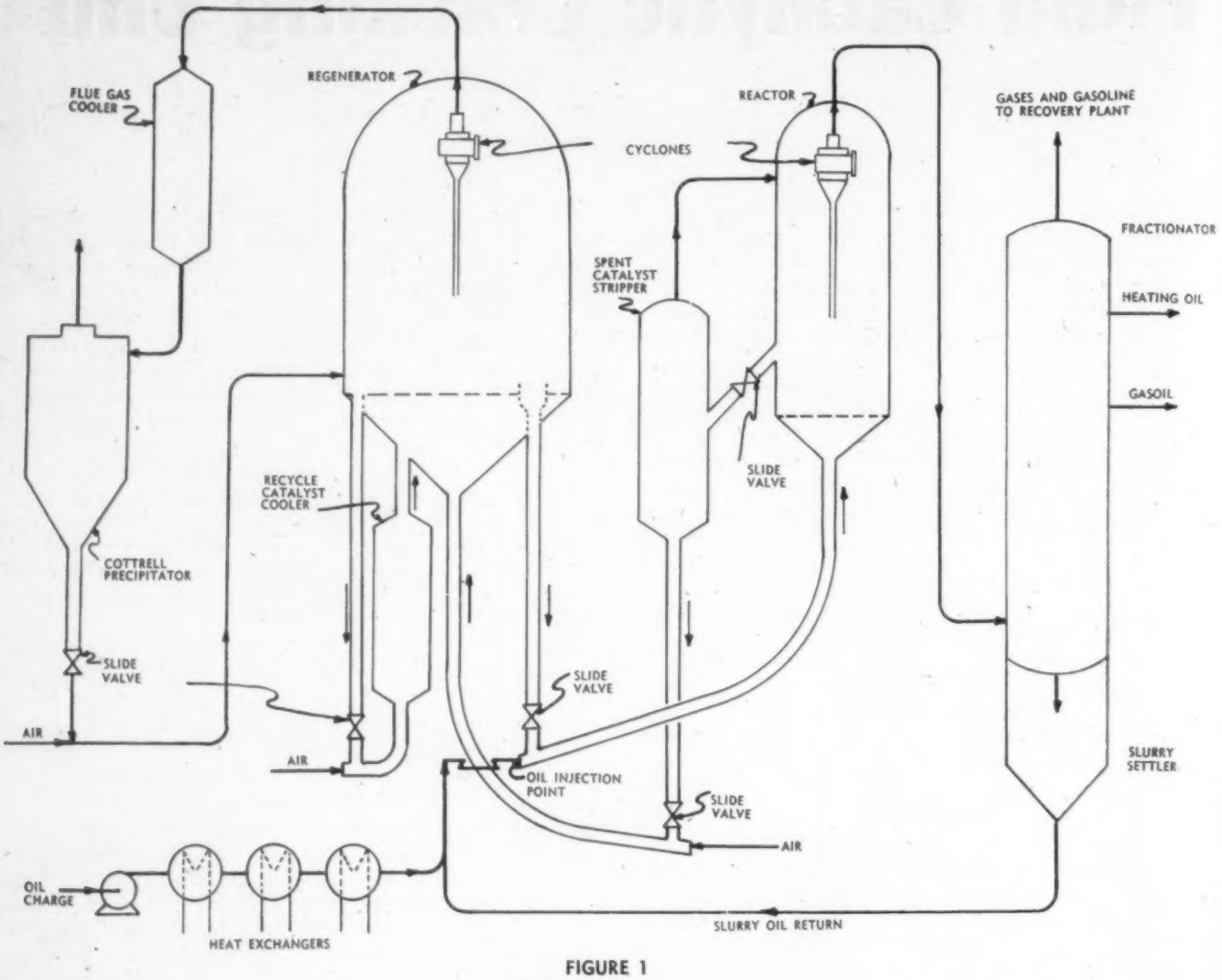


FIGURE 1
Simplified flow diagram.

Figure 4 is an outline sketch of the catalyst system which shows how the continuous cycle of the catalyst flow through the reaction and regeneration phases is automatically controlled. The main point of process control is where the mixed oil vapors and catalyst enter the reactor. The temperature recorder-controller, having its thermocouple at this location, positions the slide valve in the standpipe carrying regenerated catalyst from the regenerator to the

stream of vaporized oil charge. This controller determines the rate at which hot catalyst is fed to the hot-oil stream and thus holds a constant reaction temperature.

Reference to Figure 4 will show that a pressure-differential controller positions a slide valve in the line carrying spent catalyst from the reactor. If the temperature controller of the reactor demands more catalyst to maintain the reaction temperature, the catalyst level in the reactor will tend to rise. The pressure-differential controller offsets this tendency by opening the slide valve the proper amount to hold the level.

Catalyst level in the spent catalyst stripper is similarly controlled by a pressure-differential instrument which activates a slide valve at the base of the standpipe. By automatically opening this valve the proper amount, more catalyst is returned to the regenerator and the system balance is maintained.

The recycle-catalyst cooler circuit is necessary to control the temperature in the regeneration phase of the process. The two slide valves in the standpipe are each controlled by an automatic controller. One is positioned by an electronic recording controller which determines the rate of catalyst flow through the recycle-catalyst cooler. This cooler generates steam which is put back into the main steam system so that the removed heat is conserved.

The cooler tubes would become clogged if the temperature controller demanded too high a flow. As an increase of flow increases the pressure differential across the cooler, a controller measures this differential and governs the other slide valve in the circuit as an overriding controller of the temperature control so that if the temperature controller demands too high a flow the pressure - differential instrument closes its valve to limit the flow to a predetermined maximum.

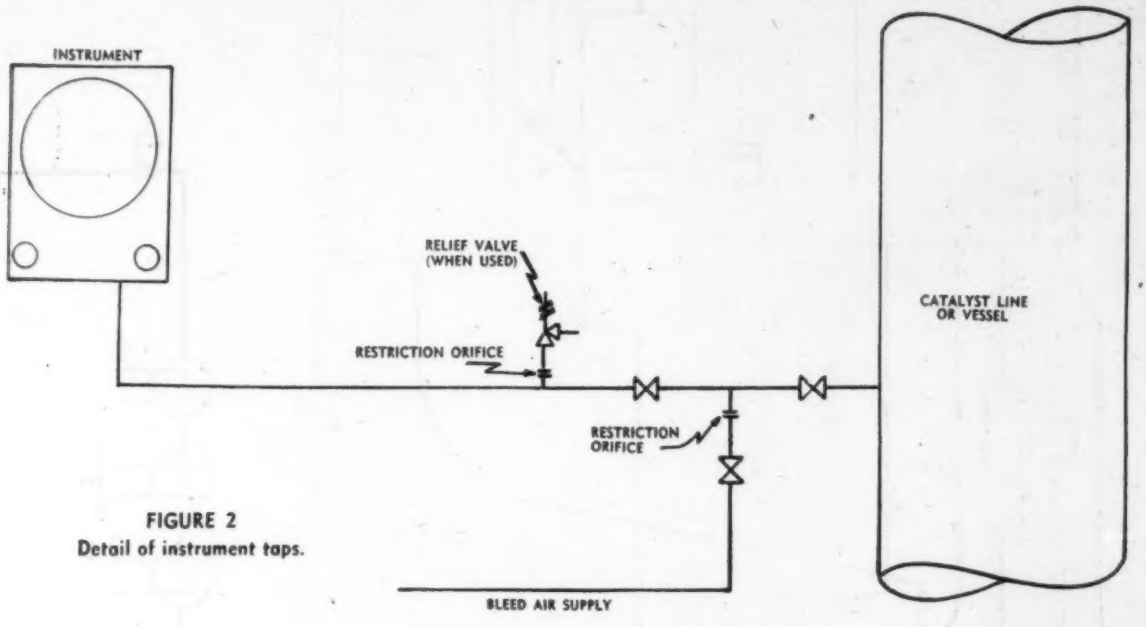


FIGURE 2
Detail of instrument taps.

The carrier air system is so designed that a constant pressure is maintained on the centrifugal compressor discharge header while the various branches of the system are automatically controlled by rate-of-flow controllers. This system was selected because of the constant header pressure and economy of steam consumption of the steam turbine driving the compressor.

The aeration-air-system control is similar to the carrier-air system except that instrument type pilots are not provided for the two compressors running in parallel but the constant discharge pressure is controlled by a combination speed and unloader control built into the governor supplied with the compressors.

Slurry Withdrawal

Slurry is withdrawn from the bottom of the fractionator tower at a constant rate by a rate-of-flow controller which controls the steam to the pump to avoid the necessity of having a control valve handle the highly erosive slurry steam. Because of this erosive action, the primary measuring element of the meter is a venturi tube with flushing oil bled into the taps to prevent blockage by catalyst.

Heat removed from the system is conserved by causing it to generate steam which is returned to the main steam sys-

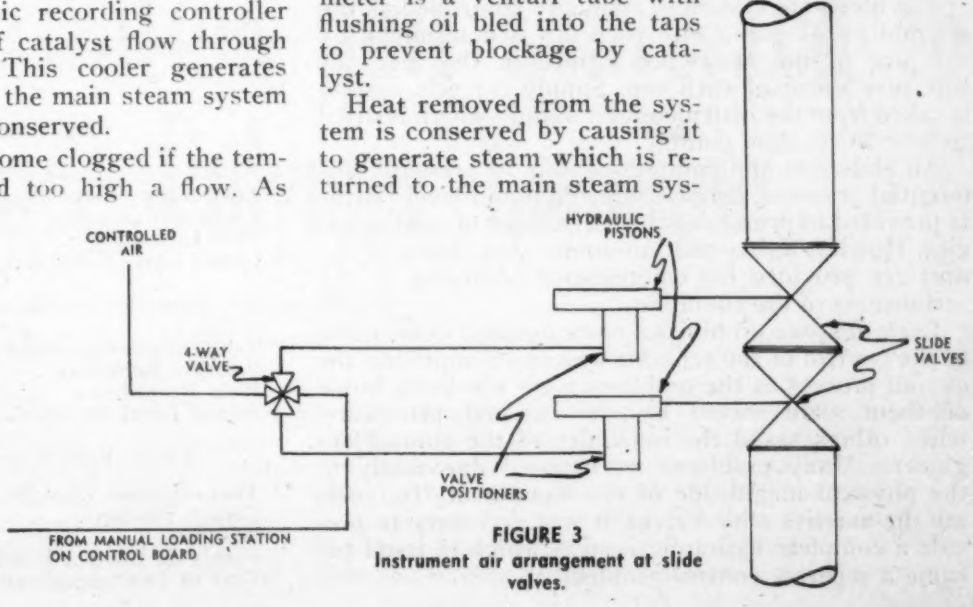


FIGURE 3
Instrument air arrangement at slide valves.

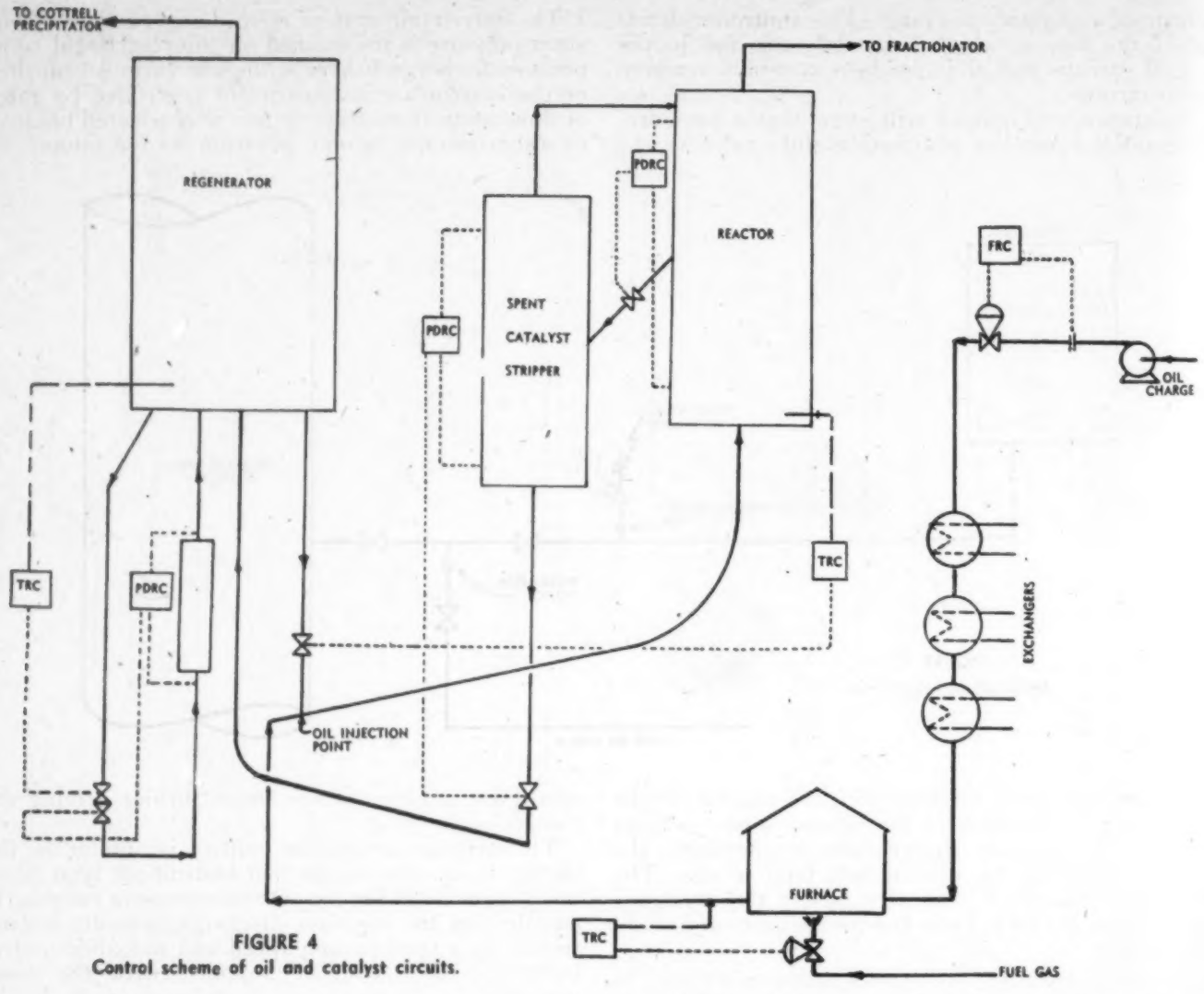


FIGURE 4
Control scheme of oil and catalyst circuits.

tem. Control of this system is very simple and follows the general design of boilers according to steam-plant practice. An exception is that a pressure controller is provided to maintain a pressure on the boiler drum rather than on the steam header so that heat is removed in the form of steam at a rate dictated by the demand for heat removal in the cooler. The water levels in the drums are controlled by conventional boiler-house type feed-water regulators.

The bleed-air system is manually controlled as the amount of air going into each tap is determined by the size of the restriction orifice in the bleed-air line just ahead of each tap. Supply for this system is taken from the instrument air supply which is dried to a — 30° F. dew point.

An elaborate and complex system of pressure, differential pressure, temperature and liquid-level alarms is provided to protect against a number of contingencies. Howler, lights and automatic shut down of the unit are provided for emergencies according to the seriousness of the condition.

Lack of space prohibits a more detailed description of the control of the separate systems comprising the overall process as the problems were manifold. Some of them were solved by conventional procedure, while others taxed the ingenuity of the control engineers. Many problems were posed due solely to the physical magnitude of the equipment. To operate the massive slide valves, it was necessary to provide a complete hydraulic system which in itself became a separate control problem.

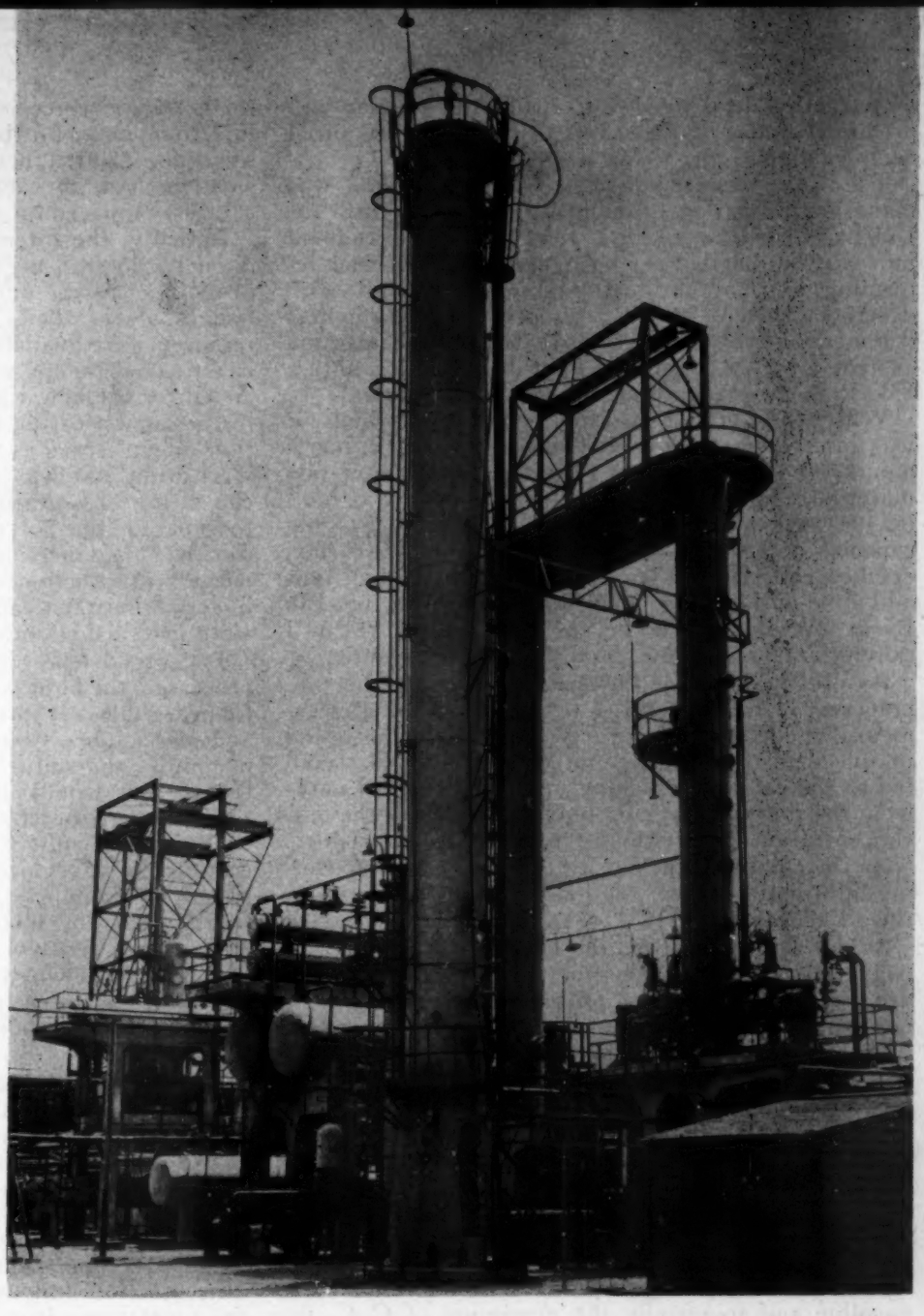
The following statistics will give some idea of the physical magnitude of a typical large fluid catalytic cracking unit.

PROCESS EQUIPMENT

Reactor	Diameter, 23 ft. Height, 50 ft.
Regenerator	Diameter, 38 ft. Height, 40 ft.
Carrier Air Compressor	Capacity, 50,000 cfm. Motor Rating, 5,200 H.P.
Slide Valves	Diameter, 34 to 42 in. Weight. 18,000 lb. Cost, approx. $10,000 each.

Instruments and Controls

Item	Number Required
Temperature Controllers	12
Pressure Controllers	27
Flow Controller	31
Liquid Level Controllers	18
Total—Controllers	88
Temperature Recorders	7
Pressure Recorders	18
Flow Recorders	23
Liquid Level Recorders	6
Total—Recorders	54
Thermocouple Lead Wire	33,000 ft.
Copper Tubing	38,000 ft.
Alarms	25
Panels on Control Board	38
Cost of Instrumentation (less slide valves)	$85,000



View of former isomerization reactor, the lower portion of which now contains solid phosphoric acid polymerization catalyst.

Idle Isomerization Unit Converted to Produce Polymer Gasoline

W. R. NEWMAN
Vice President, Frontier Refining Company, Cheyenne, Wyoming

SUCCESSFUL conversion of a wartime butane isomerization unit to a non-selective catalytic polymerization unit has been accomplished by Frontier Refining Company of Cheyenne, Wyoming.

The cost was about $14,000. It was found necessary to install only one piece of new equipment to effect the change-over, which was engineered by Universal Oil Products Company. The job was done in about three weeks by the regular refinery force.

The converted unit has been operating for more than three months, producing 150-200 barrels per day of 10-pound R.V.P. motor polymer, increasing the total gasoline production of the refinery by 5 to 7 percent and effecting substantial savings in the amount

of tetraethyl lead needed to bring the regular and premium grades of Frontier gasoline to the required octane rating.

The No. 2 refinery in which the conversion was made is an aviation gasoline plant built in 1943 for Defense Plant Corporation. It consists of a crude-oil unit of 3200 barrels per day capacity, a thermal reforming unit, a fluid catalytic cracking unit with design capacity of 2600 barrels per day (the smallest commercial unit in the world), a gas-concentration system, a U.O.P. hydrogen fluoride alkylation unit, a U.O.P. isomerization unit, and a treating plant.

When the aviation-gasoline refinery was built, it was interconnected by pipe lines to No. 1 refinery, about 500 yards away, to permit interchange of raw materials and products. No. 1 plant, which was built in 1941, consists of a topping unit with charging capacity of 4500 barrels per day, a U.O.P. thermal cracker, capacity 700 barrels per day, an asphalt unit and lube-oil-blending facilities. It operates on Elk Basin (Wyoming) crude, a black oil of 28 API gravity and containing about 2.3 percent sulfur.

As operated during the war, gasoil from the topping unit in Refinery No. 1 was piped to the government-owned plant, where it was added to the gasoil produced in the topping unit of Refinery No. 2 and fed to the catalytic cracking unit. The cracked gases from the thermal-cracking unit were fed into the gas-concentration unit with the liquid and gas products from the catalytic cracker, for the purpose of recovering light hydrocarbon fractions to be used as feed for the alkylation unit.

When the war ended, the company was eager to convert as speedily as possible to the manufacture of products it could make to the best advantage for civilian markets. Therefore, it was decided to continue and increase the production of higher-grade motor gasoline and at the same time to develop a market for bottled gas which would offer an outlet for the C_3-C_4 fractions.

With these objectives in mind, the company leased the facilities of Refinery No. 2 from the government. Of these facilities it was intended at first to operate only the fluid catalytic cracking unit and the gas-concentration unit, the former to make cracked gasoline of superior quality and the latter to stabilize the gasoline and to recover the maximum of C_3-C_4 for bottled gas.

A study of the gas concentration system with a view to simplifying it and reducing operating costs, and to consider the entire refinery picture as well, disclosed two things:

First, that the cost of operating the existing gas-concentration system was very little greater than the cost of operating a simple absorber-stabilizer system, and it had the advantage of recovering the maximum of light hydrocarbons.

Second, that because of the growing market for gasoline, the light fractions could be converted to polymer gasoline more advantageously than they could be marketed as bottled gas.

A review of the equipment available at the idle alkylation and isomerization units disclosed that a large portion of the equipment in the latter could readily be converted to a polymerization unit. It appeared that the conversion would be simple, requiring few piping changes or additions of equipment. The accompanying flow diagram shows the changes that were made.

The additional equipment specified for the conversion consisted of three G-fins to afford more surface for heating the feed to the poly reactor, two water-injection pumps for the maintaining of proper catalyst hydration, and a new filter pot for collecting the small amount of catalyst fines liberated when new catalyst is placed on stream.

Actually, the filter pot, a vessel of 24-inch inside diameter, 5 feet high and suitable for 500 pounds pressure, was the only piece of new equipment that had to be installed. The other miscellaneous items required were available in the refinery. Two existing caustic-feed pumps were rebored and new trim was added for the new water-injection service.

Conversion of the reactor tower of the isomerization unit to serve as the catalyst tower for the polymerization unit was a simple matter, requiring only the fitting of a grating in order to make it possible to separate the polymerization catalyst into two 7-foot beds. Connections were added to the tower to permit introduction of a quench stream and water injection between catalyst beds. Four thermocouples were installed to measure catalyst temperatures.

Because of the high sulfur content of the crude processed, the light fractions produced in cracking the topped crude and gasoil are high in hydrogen sulfide and mercaptans. Consequently, it becomes necessary to remove the sulfur compounds from the poly-plant feed as they would otherwise become concentrated in the polymer, thereby reducing its blending value.

The sulfur content of the C_3-C_4 fraction when operating the gas-concentration unit for maximum recovery of propylene and butylenes was known to be of the order of 1500 grams of combined H_2S and mercaptans per 100 cubic feet. This sulfur content can be held down to approximately 100 grams per 100 cubic feet by operating the deethanizer and other columns under conditions that give less than maximum recovery of propylene.

The use of a regenerative type H_2S removal system was given consideration as a means for obtaining removal of a major portion of the sulfur compounds from the poly-plant feed. However, making provision for such facilities would have delayed the start-up of the poly unit and would have increased the cost of making the conversion. It was decided therefore to start the operation in such a manner that the gas-concentration unit would reject the bulk of the H_2S and mercaptans from the poly-plant feed, postponing the installation of a regenerative type H_2S removal system.

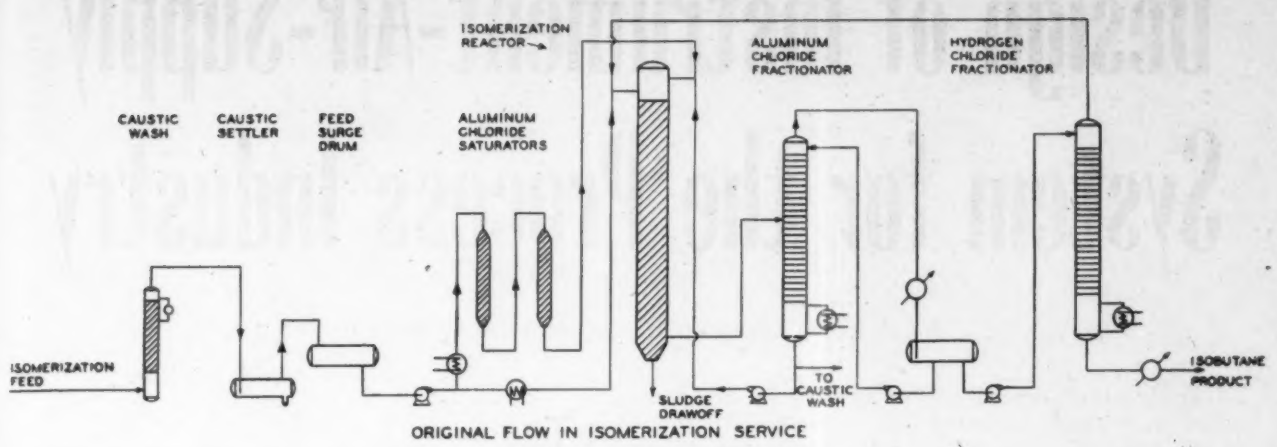
Following is a general summary of the manner in which the gas produced in the catalytic cracker is handled through the gas concentration and polymerization units.

The cracked gasoline and gases from the catalytic-cracking unit are fed into the gasoline stripper of the gas-concentration system, the bottoms from which is used as absorption oil in the deethanizer into which passes the gaseous and liquid overhead from the gasoline stripper. The deethanizer now, as before, is operated to remove all gases lighter than the propane-propylene fraction.

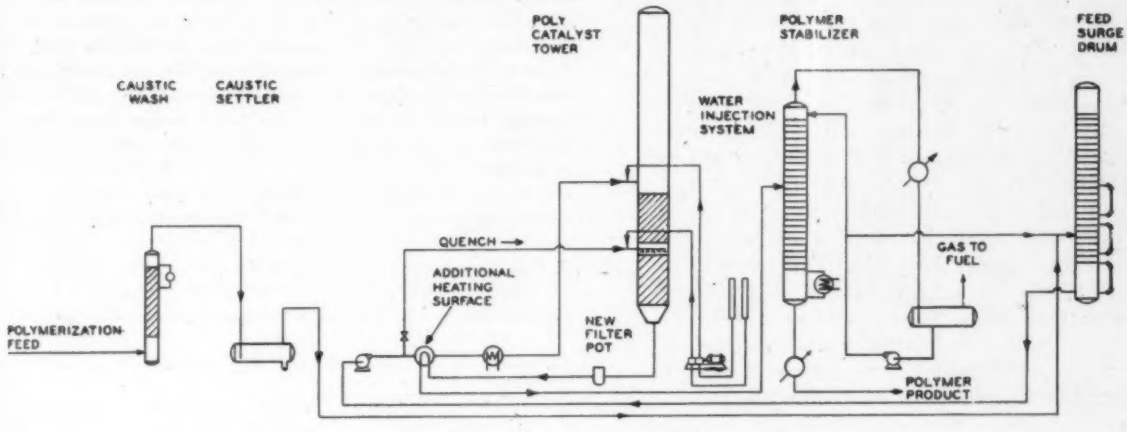
The deethanizer bottoms stream is sent to the former depentanizer which now acts as a debutanizer to separate the C_3-C_4 fraction from the catalytically cracked gasoline. A low vapor-pressure gasoline is produced as bottoms from this column in order to recover all possible of the C_4 fraction for polymerization-plant feed.

The liquid C_3-C_4 fraction obtained as a net overhead stream from the gas-concentration-unit depentanizer is pumped through a caustic wash on its way

CONVERSION OF ISOMERIZATION UNIT TO POLYMERIZATION UNIT
FRONTIER REFINING COMPANY



ORIGINAL FLOW IN ISOMERIZATION SERVICE



PRESENT FLOW IN POLYMERIZATION SERVICE

to the polymerization unit for the removal of H_2S and mercaptans. Thus is produced a low-sulfur polymer having optimum blending octane number.

The fresh C_3-C_4 feed is collected in a combined feed surge drum where it is mixed with a low-olefin-content recycle stream from the polymer stabilizer overhead. The recycle stream is used to dilute the olefin content of the feed to the catalyst tower so that the temperature rise occurring in the catalyst beds, as a result of the exothermic polymerization reaction, will not be excessive. Typical analyses of the fresh feed and recycle are shown in Table 1.

The fresh feed normally contains 45-50 percent C_3 and C_4 olefins. Sufficient recycle is used to obtain a combined feed having an olefin content of approximately 20-22 percent.

The combined feed is then pumped through an exchanger to recover the heat from the catalyst-tower effluent, through a preheater, and then into the catalyst tower. The temperature of the feed to the catalyst tower is controlled to give the desired degree of olefin conversion without exceeding a maximum of 450° F. at any point in the catalyst beds.

Under normal operating conditions when processing a 20 percent-olefin-content combined feed the temperature in the catalyst beds will range from 350-380° F. inlet to 430-450° F. outlet.

The conversion of olefins obtained at these temperatures has been of the order of 90-95 percent.

Effluent from the catalyst tower is fed to the column which formerly was used for aluminum chloride recovery in the isomerization process but is now used as a polymer stabilizer. The net overhead from this stabilizer is released to the fuel system. The condensable portion of the polymer stabilizer overhead stream is used for reflux as well as recycle.

The bottom fraction from the polymer stabilizer is high-vapor-pressure polymer which is blended directly with the catalytically-cracked gasoline. Sufficient butanes are retained in the polymer to control the vapor pressure of the total gasoline make of No. 2 refinery.

Thus, the polymerization unit is producing on an average of 150 to 200 barrels daily of 10-pound Reid vapor pressure polymer gasoline having an ASTM octane rating of 81-83 and a research octane rating of 95-97.

A typical analysis of the product from the polymerization unit is shown in Table 1.

TABLE 1

Fractional Distillation Analyses of Feed and Products at the Polymerization Unit

	Fresh Feed Mol. Percent	Recycle Mol. Percent	Polymer Liq. Vol. Percent
Propylene	15.7	0.5	....
Propane	14.1	36.3	....
Isobutane	21.8	46.7	10.4
Butylenes	36.2	2.2	2.4
Normal butane	12.2	14.3	11.9
Isopentane	....	....	1.0
Normal pentane	....	....	1.8
Hexanes†	....	....	72.5
Sp. Gr.	....	....	0.7015
Olefine content	51.9	2.7	....
R.V.P.	....	....	23.3
E.P.	....	....	417 °F.

Design of Instrument-Air-Supply System for the Process Industry

W. C. LUDI, Standard Oil Development Company

THE purpose of this paper is to outline present practice in the design of instrument-air-supply systems for process units. These systems are important in plants using automatic control instruments since continuous satisfactory performance is essential to the production of specification products and the maintenance of operator morale. For purposes of design, basic engineering data are given on pressure requirements and instrument air consumption. Also included is a discussion of instrument-air drying methods and systems, and notes on the principal design features desired in the mechanical equipment of instrument-air systems.

This paper was presented in Pittsburgh, Pennsylvania, on September 18 at the first National Instrument Conference and Exhibit of the Instrument Society of America.

IN THE DESIGN of any utility system for a process industry, certain fundamental principles are involved and carefully followed to provide an adequate and continuous supply of the utility, thereby assuring continuity of process operation and maintenance of product quality. Considerable study therefore is given in the process designs of a new operation to the utility requirements such as fuel, steam, power, cooling water and compressed air. Of equal importance to these utilities is the compressed air required for the operation of the process control instruments. In most cases these are penumatically actuated, and on their successful performance depends almost entirely the satisfactory operation of the process unit as a whole. It is with the design of the instrument-air-supply system that this paper is concerned, and the subsequent discussion will attempt to outline the principal points to be considered in such a system to insure optimum efficiency of the control instruments.

Fundamental Requirements

For successful operation of any pneumatic control system, compressed air having definite characteristics and qualities is required. The fundamental requirements are, reliability of supply, constant pressure, cleanliness and dryness. Most instrument-air-supply systems meet part of the requirements only.

Reliability of Air Supply and Constancy of Pressure

The supply should be reliable, dependable and at a constant pressure for 24 hours a day, 7 days a week. If this qualification is not met, many instrument failures will occur because of the lack of actuating air. The actuating air supply may fail for only a very short time yet cause a process unit to be upset for some period of time. This usually has a serious effect on the products and frequently makes it necessary to reject the products during this period of upset. To have a source meet the requirement of reliability, it is desirable to have certain auxiliary equipment cut-in automatically when a condition of either partial or total failure of the normal supply occurs. Much consideration must be given to this point to assure that all possibilities of failure are engineered out of the system in the simplest and most positive manner.

In most large processing plants the general yard air system at first glance appears to be a good source of supply. The air usually is available throughout the plant at reasonable pressures, at all hours, and might be assumed, therefore, that this air supply meets the requirements of reliability and constant pressure. However, this is not entirely true. The general yard air system is used for many purposes in the plant which frequently makes such demands as to result in reduced pressures in various points in the system. Such cases would be the blowing out of lines, operation of all types of air tools, pressure testing of lines and vessels, and many other sundry uses. Analyzing this supply further to determine if it meets our requirements, assume that the air is being used to blow out a long line filled with caustic and that this operation might require 30 minutes. This is what can happen: The valve on the air line is opened into the caustic line and since some time is required, the operator will leave to perform some other functions. At the end of 30 minutes, the line will have been blown clear, and since no one is at hand to shut the valve, the air can blow free and to the full capacity of the line, causing a drop in pressure. Cases have been noted in such operation where the supply pressure in the system has dropped to but a few pounds. Again assuming that air tools are being used and pressure testing is also being carried out, air required for these operations is intermittent, which may result in severe pressure fluctuations that can drop the supply pressure to a point at which instruments will not operate satisfactorily. As a typical example where all three of the preceding operations were being carried out simultaneously, the supply pressure dropped from a normal 100 psig to 20 psig throughout the system. The demand on the system was such that the pressure was not restored to a staisfactory level for instrument operation (25-30 pounds) for some time. As a result, instruments throughout the plant were controlling erratically and the operation was unsatisfactory.

Cleanliness

For all practical purposes, there are two types of contaminating materials which must be removed

and kept out of the system to insure continuous trouble-free instrument operation, namely, oil and solid matter. The solid matter may be classified as dust, dirt and scale. Elimination of these contaminants must be effected to assure delivery of clean air to the controller mechanism. As we all know, solid matter may completely plug nozzles, restrictions and pilot valves, resulting in complete controller failure. Oil can have equally as bad effect as solid matter, as oil often oxidizes and gums up the moving parts, resulting in erratic and unsatisfactory controller action.

A case comes to mind where a controller mechanism was dripping with oil which had been carried into it by the actuating medium. After an investigation, it was learned that an excessive amount of oil was being fed to the compressor to permit the oil to be carried into the air stream to assist in the lubrication of air tools. This excessive amount of oil caused a great deal of gum formation in the pilot valve and nozzles, requiring frequent cleaning of the controller mechanism.

Another instance was observed where the general yard air system was being used for the instrument-air supply, and it was necessary to blow out a caustic line. Pressure in the caustic line was higher than in the air line, and when the air valve was opened, caustic backed into the air-distribution system. Check valves had been provided to prevent a back-flow, but these valves did not hold, resulting in a flow of caustic into the air lines. This caustic was carried into the instruments, causing severe corrosion of the controller mechanism and resulting in complete controller failure. Until such time as this caustic was completely eliminated from the air system, service interruptions and high maintenance costs were experienced.

Dryness

The presence of moisture in an air system has many undesirable effects both in the distribution system and controller operation. Moisture is present in all compressed air and will be a constant source of trouble when not adequately removed. In some systems, aftercoolers are provided to remove some of the moisture, but in most cases they are inadequate.

Air contains water vapor in varying quantities, the amount depending upon specific atmospheric conditions. Air that is far from saturated under normal conditions, when compressed to a small volume and cooled to its original temperature, will precipitate moisture as the saturation point or dew point is raised due to the reduction in total volume. During compression the temperature is raised and consequently the moisture may not condense out, but remains in the air as water vapor. As the air travels from the compressor to the point of use, it is cooled to the ambient temperature, thus reducing its moisture-carrying capacity and causing some of the water vapor to be condensed and settle out in the receiver, piping, tubing and instruments.

Moisture will have various ill effects, all of which will cause unreliable instrument performance and interruption of service. Some of the chief effects are as follows:

(a) Freezing of the water where low temperature is encountered, causing loss of air supply to a single control mechanism, a group of control mechanisms or an entire area.

(b) Corrosion of piping and connections, causing rust scale, dirt and dust.

(c) Condensed water vapor and any entrained oil in the air can become emulsified, resulting in fouling of the control mechanism.

As an example of what can happen to control systems when compressed air used for instrument actuation is improperly dried, a plant was visited where the control equipment had been giving very poor results. In this plant, most of the poor instrument operation occurred during the night and early morning, and after considerable observation during these periods of upset, it was discovered that quantities of water caused by the low temperatures existing during these periods were getting into the control mechanism. In one particular instrument which was at the end of the air line, water was squirting from the pilot valve and nozzle at frequent intervals. Examination showed approximately two inches of water in the bottom of the instrument case.

When conditions as outlined above occur, it is impossible to get the most out of control equipment and to have continued satisfactory operation. The morale effect on the operating personnel is bad, and confidence in the control equipment is lost, with the result that for the slightest reason, whether the instruments are performing properly or not, hand control is quickly resorted to. When control equipment is put on hand control, frequently more operating personnel and instrument technicians are required, increasing operating cost unnecessarily. Many factors are involved when economically justifying an expenditure of money to properly condition the instrument air. To date no good cost figures are available on instrument maintenance with an air system meeting the above requirements and one which does not. Also, no figures are available as to the portion of the costs due to product rejection and reduced plant capacity which might be chargeable to instrument failure. It is believed that if these figures were available, the economics would very much favor installation of a good instrument-air-supply system and pay a handsome return on the investment. This is emphasized by the fact that many oil refineries now have systems including all portions recommended and some refineries have such programs included in their future construction.

Types of Instrument-Air Systems

The following are some of the types of air systems which may be used and will meet the principal requirements:

1. A central system entirely isolated for instrument actuation only. This system requires a compressor and necessary standby equipment, aftercooler, separator, air receiver, drying equipment and distribution system.

2. Using the general yard air compressors when they are reliable but giving instruments preference over all other users. Instrument air for this system is taken at the air receivers before it enters the general yard air-distribution system. This requires control equipment at the receiver to insure that the instrument system has preference over all other users, an aftercooler, if none is used between the compressors and air receiver, a separator, drying equipment and distribution system.

3. Using the general yard air compressors when they are reliable and the general yard air-distribution system, but installing necessary auxiliary equipment within each process unit or area to assure a uniform pressure. This requires a small auxiliary air compressor at each process unit or area to cut in automatically when the yard pressure drops below safe operating pressure. Also required at each take-off from the yard system are, an aftercooler, separator, receiver and drying equipment.

4. Individual air system at each process unit or area. This requires equipment essentially the same as that described under Item 1, but on a much smaller scale. This system has

the drawback that when small compressors and auxiliaries are used, it is difficult to obtain machines to give long life and minimum carryover of oil.

Many other systems can be devised which will probably meet the principal requirements but the four outlined cover the main variations. It is believed that the isolated system complete within itself as described in Item 1 will insure the best compressed air for instrument actuation and allow control equipment to operate free of actuating-medium problems.

Design of an Instrument Air Supply System

Assume an instrument-air-supply system is required for a plant having eight process areas and that a central system, isolated for instrument actuation

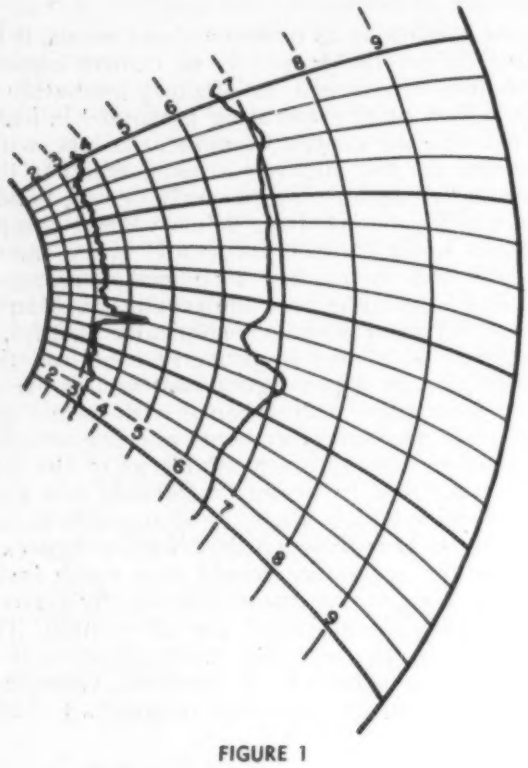


FIGURE 1

only, will be used. Before such a system can be designed, the following information is required, (a) pressure desired at the process areas; (b) air requirements in standard cubic feet per minute, also, (c) maximum and minimum atmospheric and cooling-water temperatures.

Pressure Requirements

Most instruments require an air supply at approximately 20 psig, with a few exceptions. With a reducing valve preceding the instrument, some pressure drop must be allowed for its operation, and most such reducing valves perform satisfactorily with a 5-pound pressure drop. On this basis, pressure at the process area should be a minimum of 25 psig. Experience has indicated that leeway must be allowed in the system for flexibility; hence a supply pressure at the process area of 35 psig appears to be satisfactory for most all conditions. Approximately 45 psig is required at the central station, which allows for a ten-pound pressure drop through the drier and distribution system.

Instrument Air Consumption

Air consumed by an instrument is a much discussed point and one on which widely varying figures are quoted. To clarify this point, Figures 1, 2 and 3 are given, which show actual instrument-air-consumption records of process units. Figure 1 was taken from a plant in which the majority of the instruments have the non-bleed pilots. It will be noted that the normal total flow on the chart is 3.4, and the maximum flow is 4.6, which occurred during a general plant upset. Ninety-one consuming mechanisms (pilots) were included in this plant, making the normal consumption 0.35 standard cubic feet per minute per pilot, and maximum consumption 0.44 standard

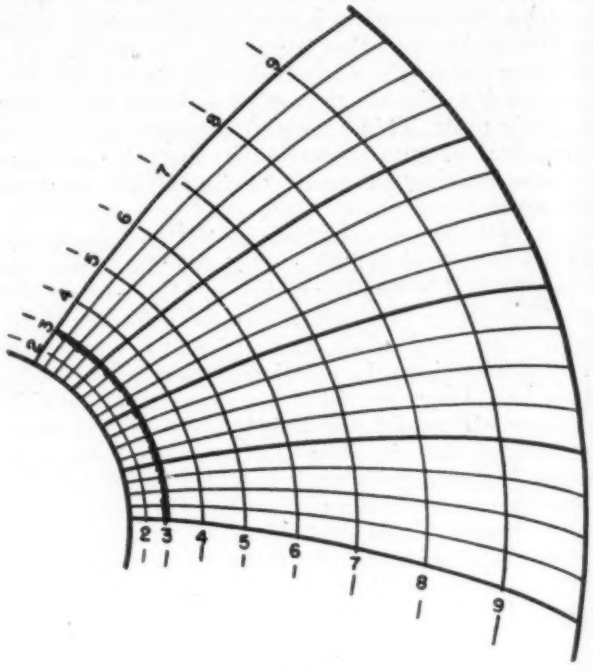


FIGURE 2

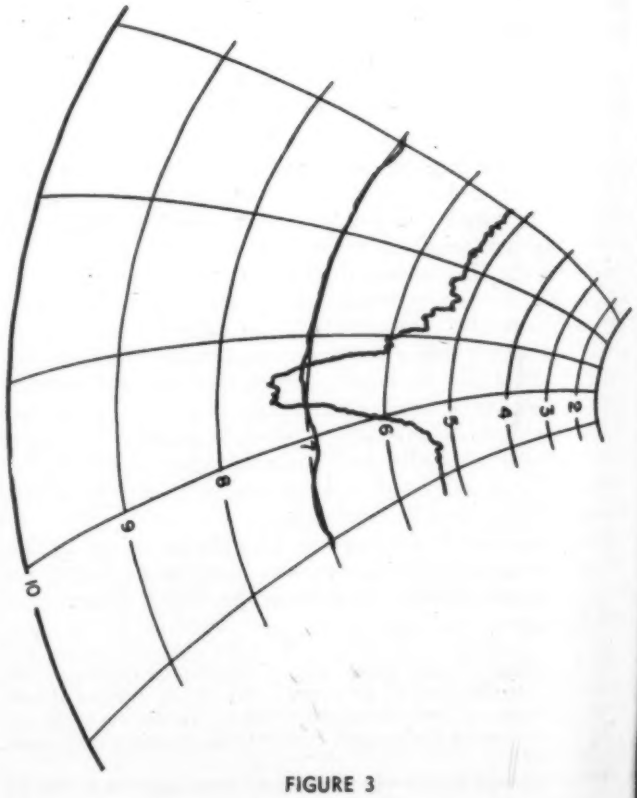


FIGURE 3

TABLE 1

Type of Instrument	Number	Weight Factor	Equivalent Users
Remote (Air Transmission type) Recorders	14	1	14
Remote (Air Transmission type) Controllers	17	2	34
Mechanical (Local) Controllers	9	1	9
Temperature Controllers	5	1	5
Temperature Controllers	1	2	2
Valve Positioners	10	2	20
Pilot-Operated Regulators	2	1	2
Miscellaneous Users	4	1	4
Total Users	90		

cubic feet per minute per pilot. Figure 2 was taken from a plant in which all the instruments have bleed-type pilots. In this case, the air is consumed at a constant rate. The total number of consuming pilots in this plant is 90, and consumption per pilot is 0.46 standard cubic feet per minute. Figure 3 is similar to Figure 1 in that the majority of instruments have non-bleed pilots, and here again the air consumption per pilot varies between 0.32 and 0.45 standard cubic feet per minute. When non-bleed pilots are used, the air rate varies considerably, but to design an air system the maximum air requirement must be available during an upset condition, and therefore it is necessary to design for this condition. A review of these data indicates that 0.5 standard cubic feet per minute per pilot is a good figure to be used as the rate of consumption of each consumer regardless of pilot type.

A tabulation of typical consumers within a single process area is given in Table 1. Each type consumer is weighted in order to arrive at a common basis. In the table, some temperature controllers have been given a factor of 2. This is done because of the number of pilots in the control mechanism. Experience and tests have also indicated valve positioners to be large consumers, and the condition of the valve can also seriously affect the consumption rate. For these reasons, positioners have also been given a factor of 2.

Table 2 is a tabulation of the air requirements for a complete plant, showing a total air requirement of 267 standard cubic feet per minute. To this figure a factor of at least 15 to 20 percent must be added to take care of leaks, blowdown and future instrument additions. In deciding on the magnitude of this factor, consideration should be given to future expansion, stability of process relative to future redesign,

The factor is based on the type and number of pilots, since some types of pilots use more air than others.

TABLE 2

Process Area	No. Control Instruments	No. Pilots or Users	Air Req'd per Unit
A	52	70	35
B	58	90	45
C	48	78	39
D	76	112	56
E	22	32	16
F	12	16	8
G	96	136	68
Total Air Required			267 scfm
Add 15 percent for leaks and future instruments			40 scfm
			307 scfm

Design system for 310 scfm.

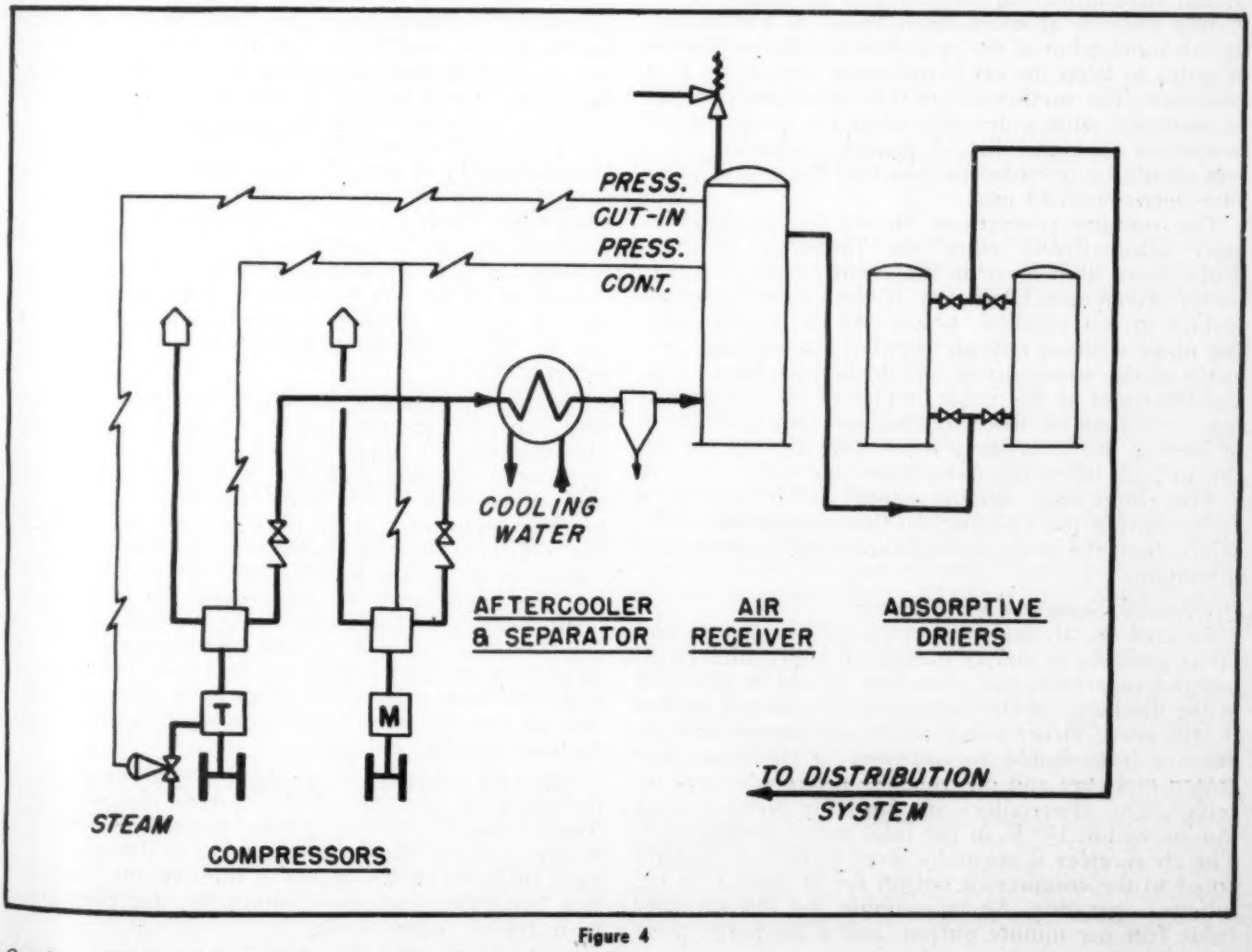


Figure 4

etc. Based on this tabulation and allowing for future instrument additions, the air-supply system should be designed for 310 standard cubic feet per minute.

Temperatures Encountered

In order to avoid deposition of moisture in the air-supply system, the air should be dried to a dew point of from 5 to 10° F. below the ambient temperature before it enters the distribution system. For design purposes, in the example being considered, the maximum and minimum ambient temperatures encountered are 95 to 50° F. summer conditions, and 0° F. minimum in winter. Cooling water temperatures vary from 75 to 35° F.

Equipment Required

Figure 4 is a line diagram for an isolated instrument-air-actuation system, showing all the pertinent equipment required, such as compressors, aftercooler, separator, receiver and drier. For the design conditions of the case under discussion, the following specific comments on equipment choice are given.

Compressors

Two air compressors should be provided, each having a minimum actual free air capacity of 310 cubic feet per minute at 45-55 psig discharge pressure. If steam and power balance permits, one compressor should be motor driven for normal operation, and one should be steam-turbine driven for standby service. These machines should be the heavy-duty continuous-service slow-speed type since this type of machine has been shown to give minimum maintenance and maximum trouble-free service. Cylinders should have force-feed lubrication with means of adjusting the rate at which lubricating oil will be fed. Splash lubrication of the cylinders should be avoided in order to keep the oil entrainment in the air to a minimum. The suction side of the compressors should be provided with a dry-type filter for removing atmospheric dust and dirt. A pressure-unloading system should be provided to maintain the output pressure between 45-55 psig.

The standby compressor should be arranged to start automatically when the discharge pressure drops below 40 psig, or in the event of failure of the motor-driven unit. Obviously, if there were no steam-turbine-driven standby, power failure would leave the plant without any air supply. The turbine governor of the steam driver should be suitable to control the speed of the turbine under all normal operating conditions in order to eliminate any possibility of having the emergency overspeed trip shut down the turbine when the compressor unloads.

The compressor suction should be located at a point outside the building, so that atmospheric contamination due to local conditions will be kept at a minimum.

Aftercooler, Separator and Receiver

To cool the air and remove as much moisture and oil as possible by simple means, an aftercooler (with integral separator) and a receiver should be provided at the discharge of the compressors, arranged so that it will serve either compressor. An automatic condensate trap should be supplied to eliminate separated moisture and oil from the aftercooler and receiver. The aftercoolers are normally sized to cool the air within 15° F. of the inlet water temperature. The air receiver is normally sized to have a capacity equal to the compressor output for at least 1 to 1½ minutes operation. As an example, for 310 standard cubic feet per minute output, and a discharge pressure of 45-55 psig, the receiver should have a volume of 67 to 100 cubic feet.

Driers

Two principal methods of moisture removal from compressed air may be used, namely, (1) cooling, and (2) absorptive drying.

The cooling method alone can be used in locations where it is possible to cool the air 10° F. or more below ambient without having the cooling medium below 35° F. When cooling is the only means of drying, such cooling should be done before the receiver. It should be noted that even when absorptive drying is used, the aftercooler itself, is, in effect, a partial drier and serves to reduce the load on any subsequent drying apparatus.

For the typical case under discussion (310 standard cubic feet per minute), the ambient temperatures are such that the cooling method cannot be used alone; therefore, the absorptive drier must be added. An absorptive type drier should be provided through which the air shall pass before entering the distribution system. This unit shall be designed for the capacity of one compressor with air entering at 55 psig, saturated with water vapor at 90° F. for the summer condition and 50° F. for the winter condition, and shall be capable of maintaining a dew point of 40° F. for summer conditions and —10° F. for winter conditions at the outlet. The drying unit should be of the dual-tower type for eight-hour drying cycle design for semi-automatic operation. The dryer should be water cooled and designed for either steam or electric reactivation.

It is interesting to note that these driers, when designed for summer conditions, will be amply large for the winter conditions. The duty requirements are not as severe in low temperatures as at elevated temperatures. Driers for such a system may be purchased as a unit complete with all reactivating equipment.

To summarize, operating experience has indicated the desirability of providing separate air facilities for the actuation of pneumatically-operated control equipment. Such a system, when properly designed, provides air at a constant pressure in adequate amounts to insure continuous and uninterrupted operation of all process equipment. Also, the design of such a system provides cleaned and moisture-free air, so that instrument difficulties are reduced to a minimum.

It is firmly believed that where for such a reasonable expenditure, trouble-free operation of air-actuated instruments can be provided, the tangible return in reduced off-quality product will justify the necessary investment. Aside from this return is the intangible factor of faith of the operating personnel in the ability of control instruments to perform their functions within the process unit. When this faith is lost the investment represented by the idle instruments, which in some cases may be substantial, is also lost. The general all-around importance of instruments is slowly being realized, and for them to maintain their position in importance it is essential that all care be taken to allow them to operate with the best possible efficiency.

Many oil refineries have installed trial installations including all portions of the system recommended. These refineries, having satisfied themselves from the results of these trial installations, as to the economics have included such systems in their recent construction programs and some companies are committed to it, for all future work.

Calculation of Solvent Extraction Equilibria

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HEAVY petroleum fractions should be regarded as a continuous phase exhibiting a gradual rather than an abrupt change in properties with the increase in refining severity, thus suggesting application of infinitesimal analysis to the study of related problems. On this basis, solubility equations for petroleum products in various solvents have been developed which find application over wide ranges of solvent concentrations and temperatures. The method may be applied for comparing relative solvent efficiencies on a mathematical basis which has not been possible in the past.

In deriving the equations presented in this article, some free use of mathematics was made. This is believed jutified because of the empirical nature of the equations. It may be noted that the same free use of mathematics permits development of some additional equations correlating the solvent-extraction variables which seem to be of practical value.

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IN SOLVENT extraction of commercial materials, such as petroleum products, construction of partial and complete miscibility diagrams is of considerable importance for estimating refining losses. However, these diagrams can be obtained only by conducting a large number of experiments requiring an expenditure of considerable time and labor. This is frequently impractical because of the large variety of stocks and solvents that may be involved in such studies.

A number of attempts has been recorded in the past for predicting the results of solvent extractions on the basis of relatively few determinations,[1,7,9,10,11] but in most instances the error of such extrapolations or interpolations is considerable, often amounting to ± 10 percent.[1] In arriving at these theoretical equations the material to be extracted is regarded usually as an impurity and a sharp demarkation line is drawn between this material and the refined product. The problem is then handled by applying the classic laws of physical chemistry involving conceptions of distribution coefficients and related theories.

Raw materials, like petroleum, cannot be treated as mere mechanical mixtures of hydrocarbons. Although pure compounds may be isolated from the very light petroleum distillates, the heavy fractions contain an exceedingly large variety of individual substances present in small quantities, and their recovery in a pure state is still a baffling problem to chemists and physicists. For this reason the bulk of petroleum should be considered as representing a continuous phase showing gradual rather than an abrupt change in properties with the increase in refining severity.[3] Likewise, the solvent properties of extracting agents change in the same gradual fashion with the increase in temperature or in the quantity of solvent employed, thus suggesting application of infinitesimal analysis to the study of these and related problems.

A large number of experimental data obtained in the laboratory or found in the literature show that the plot of oil losses (L) against the quantity of solvent used (S) is closely approximated by a straight line on a logarithmic paper, provided the extraction temperature and the method of applying solvent remain unaltered. This relationship is represented by the following algebraic expression:

$$\log L = a \log S + b \qquad (1)$$

Deviations from a straight line were observed in some instances when extrapolations were carried out to an extreme well outside the practical working range. However, in many instances such deviations were found to occur because of the experimental error involved in making such determinations.

On the above basis the differential equation showing the above relationship is

$$\frac{dL}{dS} = a \frac{L}{S} \qquad (2)$$

A well known relationship states that the reactivity of a substance is an exponential function of the temperature increments. This may be expressed mathematically as follows:

$$\frac{dL}{dT} = kL \qquad (3)$$

where T is temperature and k a constant.

Equation (3) is applied frequently to physical reactions with a considerable degree of success, suggesting the possibility of employing it in derivations of equations relating to selective solvent extractions. With this assumption, equations (2) and (3) were multiplied in order to secure an expression which permits prediction of solvent losses both with the change in temperature and quantity of solvent used

$$\frac{d^2L}{dSdT} = \frac{cL^2}{S} \qquad (4)$$

where c is a constant.

The intergrated equation involves four constants, m, n, p and q, and has the following form:

$$\log L = (m + nT) \log S + (p + qT) \qquad (5)$$

The latter equation is of major importance in analyzing solvent-extraction data. The remarkable agreement obtained between the observed and calculated solubilities may be visualized from the typical results shown in Tables 1, 2 and 3. The data refer to furfural, chlorex and phenol extractions of a de-

asphalted and dewaxed Mid-Continent residuum and the basic information was published some time ago in the literature.[4]

As has been mentioned, equation (5) involves four constants. Four experiments are necessary, therefore, for constructing a complete miscibility diagram. Data presented in Table 4 and obtained on solvent extraction of a 150 Saybolt Universal viscosity at

TABLE 1

Losses in Single Stage Extractions of a Dewaxed and Deasphalted Mid-Continent Residuum with Furfural

Temperature ° F.	Solvent Vol./vol. of Oil	LOSSES (Fraction of Oil Charge)	
		Observed	Calculated
140	3	0.135	0.138
	6	0.225	0.217
	9	0.290	0.282
	12	0.325	0.338
160	3	0.160	0.171
	6	0.260	0.258
	9	0.335	0.327
	12	0.380	0.389
180	3	0.200	0.208
	6	0.310	0.305
	9	0.395	0.383
	12	0.450	0.450
200	3	0.250	0.256
	6	0.370	0.363
	9	0.465	0.448
	12	0.525	0.517
220	3	0.310	0.312
	6	0.440	0.432
	9	0.545	0.522
	12	0.615	0.597
240	3	0.380	0.384
	6	0.520	0.513
	9	0.635	0.609
	12	0.710	0.687
260	3	0.455	0.470
	6	0.610	0.610
	9	0.735	0.708
	12	0.810	0.793
280	3	0.545	0.574
	6	0.710	0.726
	9	0.840	0.828
	12	0.915	0.910

og L = (0.947—0.00220 x °F.) log S—(1.924—0.00545 x °F.)

TABLE 2

Losses in Single Stage Extractions of a Dewaxed and Deasphalted Mid-Continent Residuum with Chlorex

Temperature ° F.	Solvent Vol./vol. of Oil	LOSSES (Fraction of Oil Charge)	
		Observed	Calculated
50	3	0.195	0.199
	6	0.265	0.266
	9	0.320	0.315
	12	0.355	0.355
60	3	0.220	0.228
	6	0.305	0.305
	9	0.370	0.362
	12	0.410	0.409
70	3	0.255	0.263
	6	0.350	0.351
	9	0.430	0.416
	12	0.475	0.469
80	3	0.295	0.303
	6	0.405	0.405
	9	0.495	0.479
	12	0.550	0.540
90	3	0.340	0.349
	6	0.465	0.465
	9	0.565	0.551
	12	0.625	0.621
100	3	0.395	0.403
	6	0.535	0.536
	9	0.645	0.632
	12	0.710	0.713
110	3	0.450	0.463
	6	0.610	0.615
	9	0.725	0.728
	12	0.790	0.820

log L = (0.426—0.00014 x °F.) log S—(1.212—0.0062 x °F.)

TABLE 3

Losses in Single Stage Extractions of a Dewaxed and Deasphalted Mid-Continent Residuum with Phenol

Temperature ° F.	Solvent Vol./vol. of Oil	LOSSES (Fraction of Oil Charge)	
		Observed	Calculated
110	3	0.297	0.292
	6	0.377	0.371
	9	0.425	0.426
	12	0.468	0.471
120	3	0.302	0.308
	6	0.399	0.397
	9	0.457	0.461
	12	0.546	0.513
130	3	0.313	0.326
	6	0.427	0.427
	9	0.496	0.499
	12	0.548	0.558
140	3	0.328	0.344
	6	0.460	0.457
	9	0.540	0.540
	12	0.598	0.608
150	3	0.347	0.364
	6	0.498	0.491
	9	0.589	0.584
	12	0.648	0.661
160	3	0.370	0.385
	6	0.548	0.526
	9	0.643	0.631
	12	0.718	0.719
170	3	0.400	0.406
	6	0.581	0.564
	9	0.699	0.682
	12	0.785	0.783
180	3	0.430	0.430
	6	0.626	0.605
	9	0.756	0.740
	12	0.854	0.853

log L = (0.115+0.0021 x °F.) log S/(0.854—0.0014 x °F.)

TABLE 4

Losses in Eight Stage Extractions of a Mid-Continent Distillate with Furfural

Temperature ° F.	Solvent Vol./vol. of Oil	LOSSES (Fraction of Oil Charge)	
		Observed	Calculated
80	0.25	0.050	0.060
	0.50	0.085	0.081
	0.75	0.095	0.097
	1.00	0.110	0.110
	4.00	0.200	0.200
100	1.00	0.122	0.126
140	1.00	0.145	0.167
	2.00	0.215	0.227
	4.00	0.290	0.308
180	1.00	0.195	0.222
200	2.00	0.335	0.348
	4.00	0.475	0.475
220	1.00	0.295	0.295
	2.00	0.403	0.403

log L = (0.422+0.00012 x °F.) log S+0.00307 x °F.—1.206

TABLE 5

Extractions of 100 SUV 210° F. Mid-Continent Residuum with Fusel Oil

Temperature (T) ° F	Solvent (S) Vol./vol. of Oil	YIELD (Y)	
		Observed	Calculated
10	2.0	0.61	0.61
	3.0	0.63	0.64
	5.0	0.70	0.69
	9.0	0.77	0.75
30	2.0	0.66	0.68
	3.0	0.69	0.71
	5.0	0.75	0.75
	9.0	0.81	0.81
50	2.0	0.74	0.75
	3.0	0.76	0.78
	5.0	0.82	0.82
	9.0	0.87	0.87
70	2.0	0.83	0.83
	3.0	0.85	0.86
	5.0	0.91	0.90
	9.0	0.95	0.93

log Y = (0.141—p.00105 x °F.) log S—(0.277—0.0026 x °F.)

100° F. Mid-Continent distillate illustrate application of the method. Four experiments were conducted using one and four volumes of furfural at 80° F. and one and two volumes of furfural at 220° F. The resulting data were substituted in equation (5) for determining the desired constants. A few more experiments were then conducted in order to verify the equation. The tabulated data show that the discrepancies are certainly within the experimental error, considering that the eight stage extractions with solvent were performed in laboratory separatory funnels and not in a continuous equipment.

Although for most purposes the use of equation (5) is entirely satisfactory some modifications of it may be introduced if desired. However, this complicates the problem considerably and introduces additional constants, which usually is not justified.

For instance, corrections can be applied for variations in solvent power of the extracting medium because of the presence of dissolved oil. Assuming that the change is proportional to the quantity of the oil present in the solvent and that the solvent characteristics of this oil are substantially constant, equation (2) may be re-written as follows:

$$\frac{dL}{dS} = a' \quad \frac{L}{b'L + S} \qquad (6)$$

where a′ and b′ are constants.

The equation can be integrated by introducing a subordinate variable

$$\frac{S}{L} = V \qquad (7)$$

The integrated expression assumes the following form:

$$\log L = m' \log \left(n' + \frac{S}{L} \; p' \right) + q' \qquad (8)$$

where m′, n′, p′ and q′ are constants.

By multiplying equations (6) and (3) for introducing the temperature correction the final differential equation of the following type is secured:

$$\frac{d^2L}{dSdT} = \frac{a''L^2}{b''L + S} \qquad (9)$$

where a″ and b″ are constants.

In its integrated form equation (9) is even more difficult to handle than equation (8) and is not practical for common use. The same considerations apply to other types of equations that may be conceived along these lines, particularly in view of the excellent results secured with the simplified expressions.

Discussions were restricted thus far to selective solvents which dissolve the undesirable constituents from the oil charge. These solvents usually are referred to as those belonging to the selective-solvent-refining type. Furfural, chlorex, phenol and nitrobenzene are the most common solvents comprising this group. The second group of solvents involves the so-called precipitants which dissolve the desirable constituents and reject or precipitate the undesirable ones. The group includes deasphalting solvents, like propane or alcohols, and dewaxing solvents represented by light petroleum hydrocarbons, ketones, chlorinated solvents and others.

Equations developed for the first group of solvents apply with a few modifications to the second group. As it is commonly accepted that the word "losses" refers to the discarded portion of the oil, Equation (2) should be re-written as follows:

$$\frac{d(1-L)}{dS} = -\frac{dL}{dS} = k' \quad \frac{(1-L)}{S} \qquad (10)$$

It may be noted that the term (1 — L) represents the yield (Y) of product and by substituting this symbol into the integrated form, the following expression is secured:

$$\log Y = k' \operatorname{Log} S + c' \qquad (11)$$

where k′ and c′ are constants.

For solvents of this type a straight line is obtained, therefore, by plotting yields and not losses against the quantity of solvent used on a logarithmic paper.

The temperature correction is applied in exactly the same manner as previously described. The final equation in its integrated form appears as follows:

$$\log Y = (m'' + n''T) \log S + (p'' + q''T) \qquad (12)$$

Validity of this equation may be visualized from the typical examples presented in Tables 5 and 6. Table 5 refers to fusel-oil extractions of a Mid-Continent residuum of 100 Saybolt Universal viscosity at 210° F. The basic data used in this example have already appeared in the literature.[4] Table 6, which

TABLE 6

Losses in Deoiling Petrolatum from a 150 SUV 210° F. Mid-Continent Residuum

Temperature °F.	LOSSES (L), VOL./VOL. OF OIL					
	Observed	Calculated	Observed	Calculated	Observed	Calculated
Solvent composition:						
Benzol, percent vol.	80		65		50	
Acetone, percent vol.	20		35		50	
0	0.19	0.19	0.28	0.28	0.37	0.37
10	0.22	0.22	0.32	0.32	0.40	0.41
20	0.26	0.26	0.36	0.36	0.44	0.45
30	0.30	0.30	0.40	0.40	0.48	0.49
40	0.35	0.34	0.46	0.46	0.53	0.54
50	0.40	0.40	0.51	0.52	0.60	0.61
60	0.46	0.46	0.58	0.59	0.66	0.67
70	0.53	0.53	0.66	0.66	0.74	0.75
80	0.62	0.62	0.75	0.75	0.83	0.82

Equations employed:

80 percent benzol—20 percent acetone log L=0.00641T—0.721
65 percent benzol—35 percent acetone log L=0.00535T—0.553
50 percent benzol—50 percent acetone log L=0.00426T—0.426

TABLE 7

Estimation of Losses in Solvent Extractions of a 67 Saybolt Universal Seconds at 210° F. Coastal Distillate with Mixtures of Aniline and Benzol at 35° F.

Aniline (A) Vol./vol. of Oil	Benzol (B) Vol./vol. of Oil	LOSSES (L)	
		Observed	Calculated
0.48	0.06	0.05	0.04
0.50	0.17	0.07	0.07
0.63	0.88	0.22	0.21
1.33	1.00	0.26	0.26
2.00	0.33	0.12	0.14
2.00	1.00	0.28	0.28
3.00	1.00	0.31	0.31
5.00	0.67	0.26	0.26

Log L=0.064 log A log B+0.209 log A+0.637 log B—0.612

TABLE 8

Observed and Estimated Yields in Nine Stage Extractions of 150 Saybolt Universal Seconds at 210° F. Mid-Continent Residuum with Cresylic Acid and Propane at 80° F.

Cresylic Acid (S) Wt./wt. of Oil	PROPANE Wt./wt. of Oil	YIELDS (Vol./vol. of Oil (Y))	
		Observed	Calculated
1.0	3.0	0.84	0.84
	5.0	0.88	0.88
	7.0	0.90	0.90
	9.0	0.92	0.92
3.0	1.0	0.67	0.66
	3.0	0.73	0.73
	5.0	0.77	0.77
	7.0	0.80	0.79
	9.0	0.82	0.81
5.0	1.0	0.59	0.60
	3.0	0.67	0.68
	5.0	0.73	0.72
	7.0	0.76	0.74
	9.0	0.80	0.77
7.0	3.0	0.62	0.65
	5.0	0.68	0.69
	7.0	0.74	0.72
	9.0	0.75	0.73

log Y=0.0351 log P log S+0.0816 log P—0.148 log S—0.115

also contains published data,[3] refers to deoiling of petroleum from a 150 Saybolt Universal viscosity at 210° F. Mid-Continent residuum by the benzol-ketone process. The latter data comprise a constant volume of three different compositions applied at various temperatures. As the volume of solvent does not change, the equations involved may be simplified to

$$\log L = r\,T + s \qquad (13)$$

where L is the portion of oil or low melting point waxes dissolved by the solvent and r and s are constants.

If a mixture of two solvents of selective solvent refining type is employed, the differential equations involved are:

$$\frac{dL'}{L'} = k''\,\frac{dS'}{S'} \qquad (14)$$

and

$$\frac{dL''}{L''} = k'''\,\frac{dS''}{S''} \qquad (15)$$

In these equations L′ corresponds to losses caused by the use of solvent S′ and L″ to the losses caused by solvent S″. By multiplying these equations, the following expression is obtained:

$$\frac{dL'dL''}{L'L''} = k''k'''\,\frac{dS'dS''}{S'S''} \qquad (16)$$

where k″ and k‴ are constants.

Solution of this equation requires expression of losses caused by the individual solvents in terms of the same variable, which cannot be done conveniently without investigating the relative solubility characteristics of the two solvents. However, the following simplified expression appears adequate for practical applications:

$$\frac{d^2L}{L^2} = c''\,\frac{dS'dS''}{S'S''} \qquad (17)$$

where L refers to total oil losses caused by the two solvents, and c″ is a constant.

In its integrated form equation (17) assumes the form:

$$\log L = A\log S'\log S'' + B\log S' + C\log S'' + D \qquad (18)$$

where A, B, C, and D are constants.

The excellent agreement between the observed and calculated values by means of Equation (18) is demonstrated by the data presented in Table 7. The data were obtained from single-stage extractions of a Coastal distillate of 67 Saybolt Universal viscosity at 210° F. with mixtures of aniline and benzol at 35° F., and have already been published in the literature.[8] Similar considerations apply to mixtures of precipitants with the exception that log Y should be employed instead of log L in Equation (18).

A rather difficult problem arises with systems employing both a selective refining solvent and a precipitant which is encountered in the Duo-Sol refining process. Losses due to selective solvent are represented by Equation (2) and those due to precipitant by Equation (10). Multiplication of the two equations leads to an expression:

$$\frac{d^2L}{L(1-L)} = c'''\,\frac{dSdS'''}{s\,S'''} \qquad (19)$$

where S and S‴ refer to the amounts of solvent and precipitant employed, and c‴ is a constant.

Upon integration, Equation (19) assumes a somewhat unwieldly form:

$$(L-1)\log(1-L) - L\log L + A'L = B'\log S\log S''' + c'\log S + D'\log S''' + E' \qquad (20)$$

where A′, B′, C′, D′ and E′ are constants.

However, over relatively narrow ranges of the amounts of solvents employed, such as are normally encountered in commercial practice, the following simplified expression can be used:

$$\log Y = A''\log S\log S''' + B''\log S + C''\log S''' + D'' \qquad (21)$$

where A″, B″, C″ and D″ are constants.

Applicability of Equation (21) to usual refinery practice is demonstrated by the data presented in Table 8. The data, published some time ago[3] refer to extractions of a Mid-Continent residuum of 150 Saybolt Universal viscosity at 210° F., with propane, and with cresylic acid which contained 35 percent phenol by weight. In setting up the equations, either weight or volume fractions may be employed, as the differences arising from these two methods of presenting data are automatically adjusted by the corresponding changes in the values of numerical coefficients.

For yields below 50 percent, better correlations are obtained if log L is substituted for log Y in equation (21).

An attempt has also been made to find a mathematical relationship between oil losses and the number of extraction stages. Inspection of the available data revealed that this relationship may be expressed by the differential equation:

$$\frac{dL}{dN} = a'''\,\frac{L}{N} \qquad (22)$$

where N is the number of extraction stages and a‴ a constant.

However, while losses for a fixed number of stages vary with the temperature according to Equation (3). Temperature was found to have a somewhat different effect on variation in losses with the number of

TABLE 9

Multistage Extractions of 150 Saybolt Universal Viscosity Dewaxed and Deasphalted Mid-Conitnent Residuum with One Volume of Furfural at Various Temperatures

Temperature °F.	Temperature °R		No. of Stages	LOSSES (Vol./vol. of Oil) Observed	LOSSES (Vol./vol. of Oil) Calculated
140	600	.....	1	.....	0.044
			3	0.080	0.080
			5	0.113	0.105
			7	0.126	0.126
160	620	.....	1	.....	0.060
			3	0.099	0.100
			5	0.128	0.128
			7	0.142	0.149
180	640	.....	1	.....	0.080
			3	0.125	0.124
			5	0.151	0.152
			7	0.163	0.174
200	660	.....	1	.....	0.110
			3	0.159	0.159
			5	0.182	0.188
			7	0.195	0.210
220	680	.....	1	.....	0.142
			3	0.199	0.193
			5	0.221	0.220
			7	0.233	0.241
240	700	.....	1	.....	0.189
			3	0.247	0.239
			5	0.264	0.266
			7	0.271	0.286
260	720	.....	1	.....	0.244
			3	0.296	0.293
			5	0.313	0.319
			7	0.326	0.337
280	740	.....	1	.....	0.316
			3	0.352	0.352
			5	0.370	0.371
			7	0.383	0.383

$\log L = (13.875 - 4.802\log T)\log N - (27.362 - 9.363\log T)$

TABLE 10

Multistage Extractions of 150 Saybolt Universal Seconds Mid-Continent Residuum with Two Volumes of Furfural at Various Temperatures

Temperature			No. of Stages	LOSSES (Vol./vol. of Oil)	
°F.	°R.			Observed	Calculated
140	600	.....	1	0.120	0.120
			3	0.159	0.159
			5	0.181	0.181
			7	0.199	0.199
160	620	.....	1	0.148	0.148
			3	0.187	0.187
			5	0.209	0.209
			7	0.225	0.225
180	640	.....	1	0.183	0.185
			3	0.219	0.222
			5	0.242	0.241
			7	0.258	0.255
200	660	.....	1	0.228	0.227
			3	0.258	0.263
			5	0.280	0.282
			7	0.300	0.295
220	680	.....	1	0.271	0.267
			3	0.311	0.308
			5	0.324	0.328
			7	0.341	0.344
240	700	.....	1	0.325	0.325
			3	0.356	0.359
			5	0.376	0.376
			7	0.391	0.387
260	720	.....	1	0.386	0.387
			3	0.418	0.420
			5	0.435	0.435
			7	0.448	0.447
280	740	.....	1	0.450	0.451
			3	0.491	0.490
			5	0.503	0.508
			7	0.514	0.521

log L=(6.872—2.380 log °R.) log N—(18.893—6.468 log °R.)

stages than that represented by this equation. This variation was assumed to be

$$\frac{dN}{dT} = b'''T \tag{23}$$

where b''' is a constant.

Using equations (22), (23) and (3), the following expression was developed:

$$\frac{d^2L}{dNdT} = m''' \frac{L^2}{N\frac{dN}{dT}} = ''' \frac{L^2}{NT} \tag{24}$$

The integrated form of this equation is

$$\log L = (p''' + q''' \log T)\log N + (r''' + t''' \log T) \tag{25}$$

where p''', q''', r''' and t''' are constants, and T absolute temperature.

Data presented in Tables 9 and 10 show a very good agreement between the observed and calculated values. The data refer to multi-stage extractions of a 150 Saybolt Universal viscosity dewaxed and deasphalted Mid-Continent residuum with furfural.

Equations developed in this paper may be combined in the usual manner, depending on the type of problem on hand. For instance, a complete equation for extractions with selective-refining solvents may be obtained by multiplying equations (2), (3), (22) and (23)

$$\frac{d^3L}{dSdTdN} = A''' \frac{L^3}{SNT} \tag{26}$$

where A''' is a constant.

Equations developed in this paper may be analyzed by investigating maxima and minima of the respective functions. For example, a partial derivative of losses with respect to the number of stages using equation (25) appear as follows:

$$\frac{\delta L}{\delta N} = \frac{L}{N}(p''' + q''' \log T) \tag{27}$$

This expression becomes zero if $L = 0$, or $N = \infty$, or

$$\log T = -\frac{p'''}{q'''} \tag{28}$$

It shows that losses vary with the number of stages, depending on temperature, and that stage extractions are most effective at the temperature corresponding to that determined from equation (28).

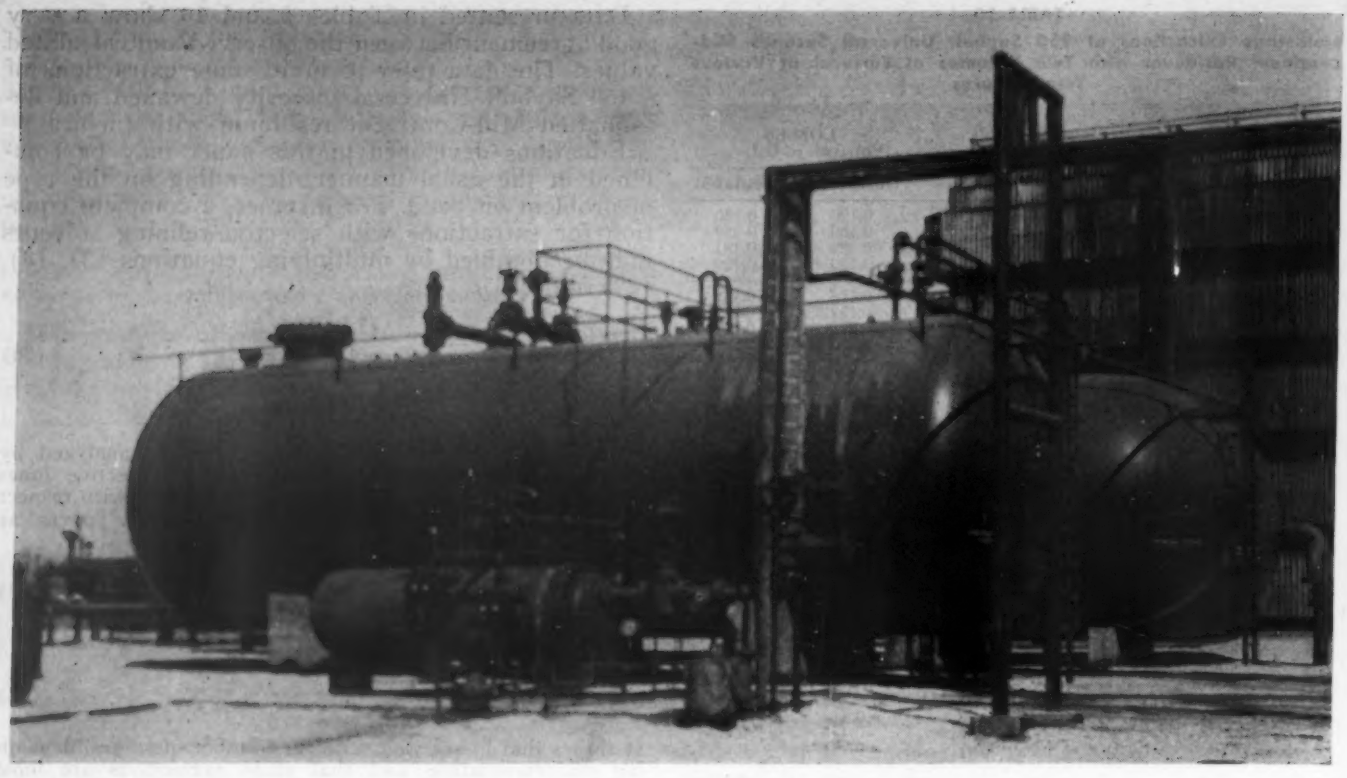
A number of other conclusions may be reached by similar analysis of the equations presented in this paper. However, such conclusions are only of general interest because small errors in determining numerical values of the coefficients involved result in very considerable differences in the results obtained.

ACKNOWLEDGMENT

The writer would like to express his appreciation to Messrs. J. W. Newton, W. W. Leach, and P. L. Smith for permission to publish this manuscript.

BIBLIOGRAPHY

[1] Hunter, T. G. and Nash, A. W., Ind. Eng. Chem. 27, 836-45 (1935).
[2] Kalichevsky, V. A., Modern Methods of Refining Lubricating Oils, American Chemical Society Monograph No. 76, Reinhold Publishing Corp., New York, N. Y. (1938).
[3] Ibid, p. 47.
[4] Ibid, p. 67.
[5] Ibid, pp. 125-7.
[6] Kalichevsky, V. A., Manufacture of Lubricating Oils, Petroleum Refiner 24, 342-6 (1945).
[7] Kurtz, S. S., Jr., Ind. Eng. Chem. 27, 845-6 (1935).
[8] Story, B. W. and Kalichevsky, V. A., U. S. 2,107,429, Feb. 8, 1938.
[9] Thiele, E. W., Ind. Eng. Chem. 27, 392-6 (1935).
[10] Thompson, F. E. A., J. Inst. Petroleum Tech., 22, 189-92 (1936).
[11] Varteressian, K. A. and Fenske, M. R., Ind. Eng. Chem. 28, 928-33, 1353-60 (1936).



Liquefied Propane Storage Insures Refinery Fuel Supply

WILSHIRE OIL COMPANY, which operates a refinery at Norwalk, California, has a conservation method of handling excess propane which has prevented an emergency shut down of the refinery upon at least two occasions. Vapors from processes are gathered and condensed for use in motor fuels, and the discard from the final process is split into liquified petroleum gases. Excess propane is condensed in water-cooled units, together with other lighter vapors, and piped to two horizontal pressure vessels included in the refinery fuel system. The liquified propane is held in the vessels at 200 psi, and released into the plant fuel lines automatically as conditions in the plant dictate.

The liquid-fuel tanks are near the gas-fuel-balance tank, and connected to the intake of this vessel so that vapors from propane storage can enter the fuel system without restriction and upon a moments notice. Ordinary plant-produced gas and gas delivered to the refinery by a commercial gas line pass into and through this balance tank. These gases usually are in sufficient supply, and during normal plant operation, the propane in the pressure vessels is held as stand-by. But when purchased gas is shut off, as can and has happened, liquid fuel is vaporized and at once fed into the fuel-balance tank to take up the slack, or until other arrangements can be made for fuel, if the emergency is of any duration.

The two propane tanks are equipped with a more or less intricate system of manifolding. The inlet and outlet are attached to flanges in the shells of the vessels at the top. Safety valves and discard lines leave at the top, but have vapor-release lines leading from the safety devices to the inlet of the fuel-balance tank, so when tank pressure exceeds the predetermined limit, excess propane can be saved as supplemental fuel rather than being popped to the plant flare. Gauge-glass columns and sample cocks are installed on each tank to indicate the quantity of propane available for emergency fuel.

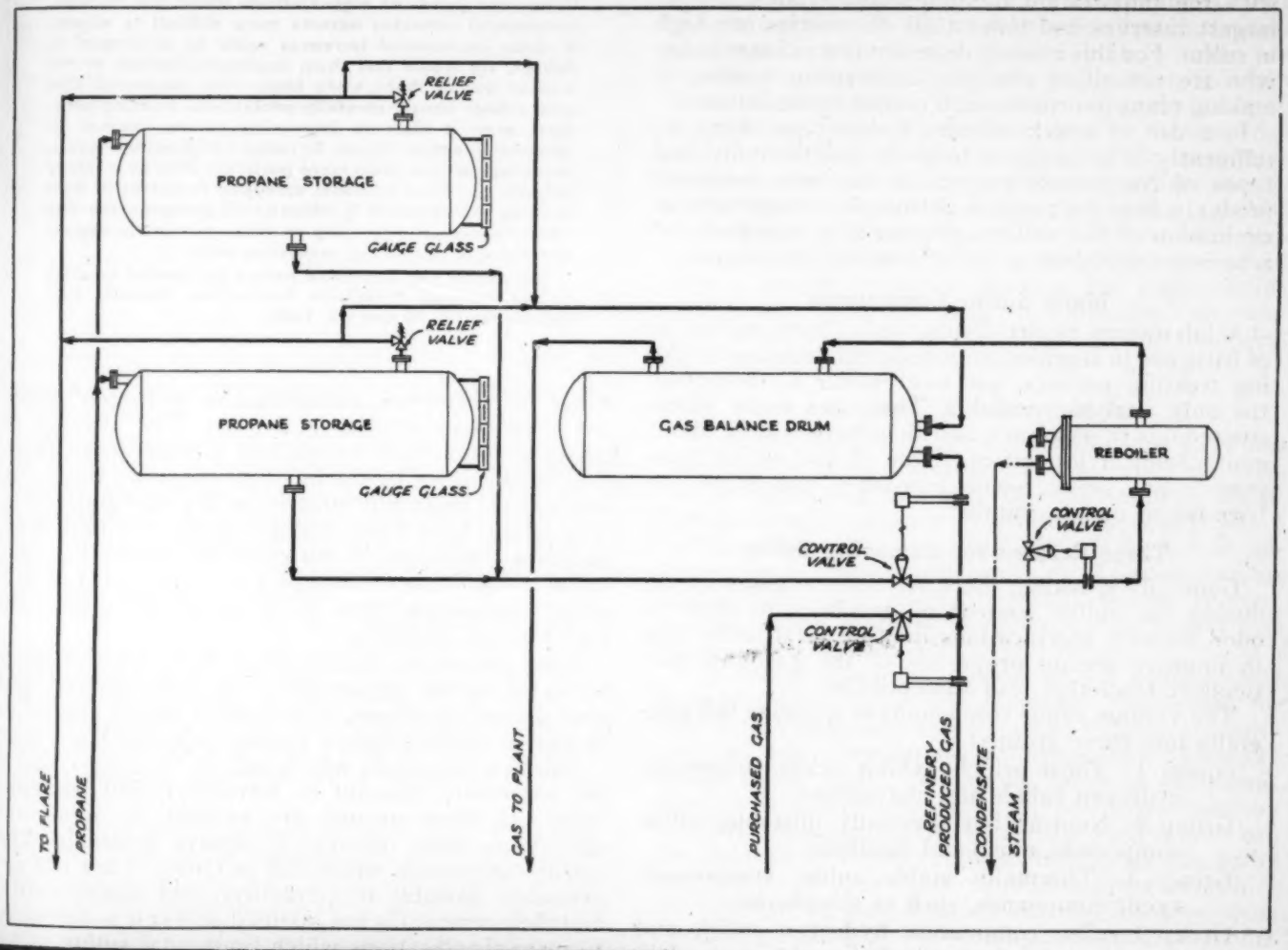
The fuel-balance tank is set beside the propane storage vessels so that commercial gas may be fed directly to the balance tank through appropriate manifolding together with supplemental fuel from the propane holders. Refinery gas flows from its source to this balance tank and supplies the major part of refinery requirements. Effective volume controllers and other instruments with meters permit commercial gas to pass into the balance tank to maintain a constant pressure and volume. So long as a normal supply of produced and pipe-line gas is available, the liquified propane remains static.

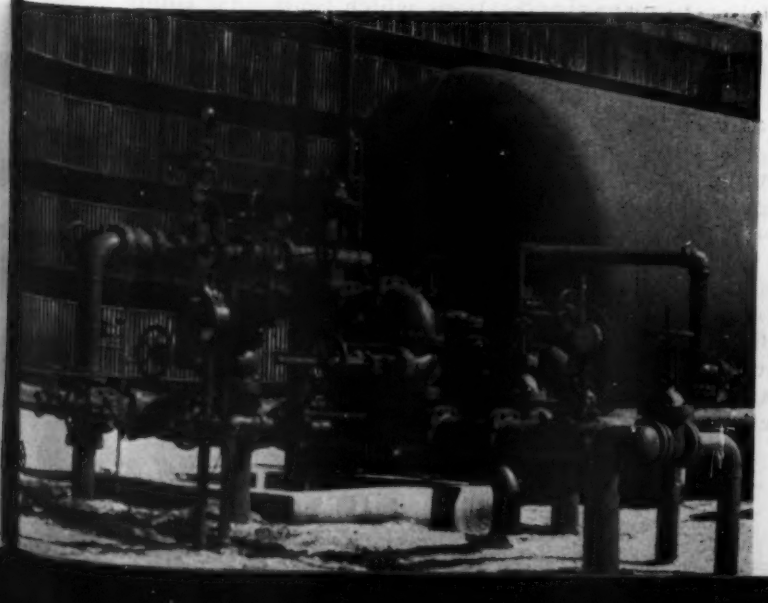
The propane stand-by storage vessels are kept full regardless of the fuel requirements of the refinery,

make-up being produced from the fractionators throughout the refinery process runs, so that a maximum quantity of fuel will be on hand for emergency. This stand-by fuel is also valuable for use when starting up the plant after a shutdown.

The liquefied propane is vaporized through an automatic unit which is in fact a steam-heated reboiler,

Right: The propane reboiler has two controls to insure operation is positive and instantaneous.





automatically controlled by thermostats and pressure instruments. During an emergency the automatic instruments and controllers on the propane tanks begin to function to release the required quantity of fuel through the vaporizer. Steam being connected to the vaporizer and available constantly, the temperature of the tubes is at a constant point, high enough that the liquid propane flowing through the reboiler is reduced to a gaseous state immediately. The controllers do not require setting for this action, as the design permits constant operation with only a superficial inspection for minor changes and an occasional adjustment.

Feeder end of gas balance tank, showing manifolding required for various inlets of gas available to insure constant supply.

An Evaluation of Sulfur Compounds in Gasolines

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DURING the years prior to the war, there was an almost continual increase in octane-number requirements and it is expected that this increase will continue in postwar years. As higher octane levels are reached, incremental increases become more difficult to obtain. If these incremental increases could be evaluated in dollars, we would find them expensive indeed. In the prewar period there were many who suggested that each refiner should carefully analyze his treating processes with a view to improving octane number or eliminating octane losses. At today's high octane levels, these suggestions seem more pertinent than ever. Many refiners may have valuable untapped resources in their treating plants which if utilized will postpone the day when it becomes necessary to make extremely expensive changes to refinery processing units.

This paper was presented before the annual meeting of the National Petroleum Association, Atlantic City, September 18, 19 and 20, 1946.

THE treatment of gasolines produced from high-sulfur crudes has always presented a serious problem and merits careful study. Many refiners, who have in the past processed sweet crudes, are now faced with the importation of high-sulfur crudes, as our largest reserves and newest oil discoveries are high in sulfur. For this reason, there are few refiners today who are not either charging high-sulfur crudes, or making plans to process such crudes in the future.

In order to attack refinery treating problems intelligently, it is necessary to study first the individual types of compounds present in the raw untreated products. It is the purpose of this paper to present an evaluation of the sulfur compounds in gasoline and a basis for establishing sulfur treating procedures.

Many Sulfur Compounds

A laboratory report, listing only "total sulfur" is of little use in reaching an intelligent decision involving treating matters, yet total sulfur is frequently the only analysis available. There are many sulfur compounds in gasolines, and they have widely divergent chemical properties. Some of the sulfur compounds are acidic, some corrosive, and some are harmful to octane number.

Three Reasons for Removing Sulfur

Generally speaking, there are three reasons for reducing the sulfur content of gasoline: to improve odor, to meet specifications limiting total sulfur and to improve certain properties of the gasoline, particularly tetraethyl lead susceptibility.

The various sulfur compounds in gasoline fall generally into three groups:

Group 1: Those which exhibit acidic properties, hydrogen sulfide and mercaptans.

Group 2: Neutral, but thermally unstable, sulfur compounds, mono and disulfides.

Group 3: Thermally stable sulfur compounds, cyclic compounds, such as thiophenes.

Group 1 sulfur compounds, hydrogen sulfide and mercaptans, can be determined directly in the laboratory.

If straight-run gasolines are catalytically desulfurized, Group 2 compounds, which are thermally unstable, will be decomposed to hydrogen sulfide, and in this manner, the Group 2 sulfur content of straight-run gasoline can be determined. Any remaining sulfur can be classified as Group 3, although straight-run gasolines do not normally contain appreciable quantities of the compounds in Group 3.

In fresh, that is to say unoxidized, samples of cracked gasoline, sulfur compounds will be predominantly those of Group 1 and 3, or hydrogen sulfide, light mercaptans and cyclic sulfur compounds. Since Group 2 usually is not present in appreciable quantities, in raw cracked gasoline, Group 3 can be determined by difference, assuming the hydrogen sulfide and mercaptan content is known. The absence of Group 2 compounds in cracked gasolines can probably be explained by the fact that these are thermally unstable. If originally present in the charging stock, they would have been changed under the high temperature conditions of the cracking process to form sulfur compounds of Groups 1 or 3. In fact, Group 3 sulfur compounds seem to be associated principally with cracked products.

After the above classifications have been made in terms of actual percentages, for both cracked and straight-run gasolines, it becomes a simple matter to choose a process suited to the individual gasoline.

Sulfur compounds which fall in Groups 1 and 2 are extremely harmful to tetraethyl lead susceptibility. If these groups are present in significant quantities, their removal is always desirable. The sulfur compounds which fall in Group 3 are not appreciably harmful to tetraethyl lead susceptibility, and their removal is not justified unless it is necessary to meet specifications which limit total sulfur.

Hydrogen sulfide must be removed from motor fuels because it is corrosive. Fortunately, hydrogen sulfide has acidic properties and is easily removed, either by simple caustic washing, or by some process involving a weak alkaline reagent which can be regenerated, such as the Girbotol or Shell T.P.P. processes. The end product of the reaction of hydrogen sulfide with caustic soda is sodium acid sulfide which cannot be regenerated by simple means. If hydrogen sulfide is present in small quantities, caustic washing usually is employed as caustic consumption will not be great, and small quantities of waste caustic usually do not require difficult methods of disposal. If hydrogen sulfide is present in higher concentrations it may be necessary to use one of the

patented processes involving reagents which can be regenerated in order to prevent a serious disposal problem and to reduce cost.

Mercaptans are weak acids, making possible their extraction from gasoline by aqueous alkaline reagents. They are malodorous sulfur compounds and must be removed from gasolines if present in significant quantities. Mercaptans can be converted to comparatively nonodorous disulfides by oxidation and processes which accomplish this are known as sweetening processes. Doctor and copper-sweetening units are examples. Conversion to disulfides in these processes is not accompanied by desulfurization as the disulfides which are formed remain in the gasoline. Mercaptan extraction is accompanied by an octane gain, because sulfur is actually removed from the gasoline. Sweetening processes, on the other hand, produce an octane loss as no sulfur is removed and the disulfides which are formed are somewhat more deleterious to octane than the mercaptans originally present.

In cracked gasolines, if the mercaptan content is known, it is a simple matter to choose the proper type of process. If the mercaptan concentration is below 0.004 weight-percent, it has been demonstrated that odor will not be a problem and further processing is not necessary, unless required to meet an arbitrary specification requiring a negative doctor test. If the mercaptan concentration of the untreated gasoline is above 0.004 percent and below 0.02 percent, it usually is possible to produce a satisfactory product with a continuous regenerative caustic scrubbing unit, as this method ordinarily will extract from 75 to 80 percent of the mercaptan sulfur present. Such sulfur removal will be accompanied by a slight increase in octane number.

Mercaptan contents above 0.02 weight-percent are most satisfactorily treated by one of the newer mercaptan extraction processes, such as the Unisol process, as these will remove substantially all of the mercaptan present and produce an octane improvement which at the 3 cc lead level often amounts to as much as 3 full numbers.

Sweetening processes are recommended only for gasolines extremely low in mercaptan sulfur, in those areas where a strict interpretation of the doctor test is required. Sweetening processes which result in a loss rather than improvement in octane number are always a burden and expense to the refiner; whereas sulfur removal processes will usually more than pay their own way.

Since cracked gasolines contain little or no Group 2 sulfur compounds, sulfides and disulfides, any sulfur remaining, after mercaptan and hydrogen sulfide removal, is usually in the form of cyclic sulfur compounds. Cyclic sulfur compounds are not particularly deleterious to octane number and, therefore, can be permitted to remain in the gasoline, unless removal is necessary due to a specification limiting total sulfur. After hydrogen sulfide and mercaptan removal from cracked gasolines, further desulfurization cannot be economically justified and will not result in an advantage to the ultimate consumer. Unreasonably low total sulfur specifications, which may require cyclic sulfur removal, are an unwarranted burden on the refiner. The process used for cyclic sulfur removal is usually treatment with sulfuric acid, a costly and wasteful process.

Assuming that hydrogen sulfide and mercaptan removal has been accomplished, any additional octane improvement on cracked gasoline must come from a hydrocarbon conversion process or a change from thermal to catalytic cracking, which considerations are outside of the scope of this paper.

To summarize, for treating cracked gasolines, some form of mercaptan extraction, either caustic scrubbing, or processes such as Unisol are recommended. Sweetening processes are never recommended, except where the initial mercaptan content is very low and a negative doctor test is required.

Straight-run gasolines contain, in addition to hydrogen sulfide and mercaptan, Group 2 sulfur compounds, which are designated as being thermally unstable, such as sulfides and disulfides. A decision concerning the treatment of straight-run gasoline depends upon the relative proportions of mercaptans and Group 2 sulfur compounds and the amount of total sulfur present. Many straight-run gasolines are low in total sulfur content and cannot be appreciably improved by catalytic desulfurization. These may contain, for example, mercaptans in the order of 0.01 weight-percent or less. Catalytic desulfurization processes usually cost between 8 and 15 cents per barrel to operate on straight-run gasolines. If it has been determined that the octane improvement from catalytic desulfurization cannot justify this expense on a low-sulfur straight-run gasoline, it usually is recommended that the gasoline be either caustic washed with a regenerated caustic process to below 0.004 weight-percent mercaptan sulfur or, if the doctor specification is necessary, that it be sweetened with a copper or doctor process. For higher-sulfur straight-run gasolines, it is recommended that catalytic desulfurization, such as the Gray high-temperature clay-treating process, be used.

Catalytic Desulfurization

Catalytic desulfurization on straight-run gasolines will usually show a marked improvement over mercaptan extraction methods, because catalytic desulfurization will remove both mercaptans and Group 2 sulfur compounds. Since straight-run gasolines seldom contain appreciable quantities of Group 3 sulfur compounds, when catalytic desulfurization is used, sulfur removal is almost complete, and an appreciable octane improvement usually will result.

By comparison, this process is not economically sound for use on cracked gasolines. The reason for this is that fresh, untreated cracked gasolines usually contain only mercaptans and relatively thermally stable cyclic sulfur compounds such as thiophene. The cyclic sulfur compounds are not decomposed by catalytic desulfurization, while the mercaptans can be removed by either catalytic desulfurization, or by the less costly mercaptan extraction processes. Since the amount of sulfur which can be removed from cracked gasolines is approximately equal for both catalytic desulfurization and mercaptan extraction, the octane improvement which follows is almost the same in either case, and the less costly of the two processes is recommended. For the treatment of cracked gasolines, the extraction processes have other advantages over catalytic desulfurization. The effective life of desulfurization catalysts, when processing cracked gasolines, is short, due to carbon deposition, and, therefore, it is necessary to resort to frequent regeneration, which adds materially to the operating cost. Since polymerization occurs in the presence of the desulfurization catalyst, rerunning, which is unnecessary for straight-run, is required when cracked gasolines are treated. While catalytic desulfurization can be operated on straight-run gaso-

lines with a loss of only 0.5 percent, a polymerization loss of several percent will occur when processing cracked gasolines. In studying laboratory results from desulfurization work on cracked gasolines, it should be remembered that the product usually has been rerun to produce a slightly lower boiling range, which may result in what appears to be a slight improvement in octane gain over mercaptan extraction. Comparative studies should be based on products of the same boiling range.

At times this process has been used on blends of straight-run and cracked gasolines. When this is done the desulfurization of the straight-run portion of the blend is depressed and the overall results are poor as compared to separate mercaptan extraction of the cracked gasoline and catalytic desulfurization of the straight-run gasoline.

Mercaptan Extraction

Occasionally a light straight-run gasoline is available which contains little sulfur except in the form of mercaptans. In this case, mercaptan extraction is recommended if the mercaptan content is significant, 0.02 weight-percent or higher. Quite often mercaptan extraction can be accomplished in a combination unit, utilizing the cracked-gasoline treating facilities. For example, a light straight-run gasoline containing essentially all the sulfur in the form of mercaptans could be caustic washed, using caustic which is regenerated in a cracked-gasoline caustic regenerator, or could be Unisol treated, using Unisol reagent which is regenerated in a regenerator common with a cracked-gasoline Unisol unit.

One factor which contributes largely to the octane improvement of straight-run gasolines when catalytically desulfurized is the rearrangement of some of the hydrocarbon molecules which takes place. We believe this to be isomerization. Numerous data showing octane improvements from straight-run catalytic desulfurization are available, which cannot be accounted for on the basis of sulfur removal alone. Any comparable molecular rearrangement in cracked gasoline seems to be negated by the polymerization which takes place when cracked gasolines are catalytically desulfurized.

To summarize, for straight-run gasolines, if the laboratory catalytic desulfurization tests indicate sufficient octane improvement to justify the operating cost, catalytic desulfurization is recommended. In those cases where the straight-run is of low end point, containing essentially all mercaptans, a mercaptan-extraction process should be used. For extremely low-sulfur straight-runs, little octane improvement is possible and usually a simple caustic washing unit or sweetening unit is recommended, depending upon whether or not a strict interpretation of the doctor test is required.

The case for sulfur removal units of the foregoing mentioned types can be made very strong indeed. Frequently, severe reforming of the straight-run gasoline can be avoided by catalytic desulfurization. These processes, particularly high-temperature clay desulfurization and Unisol treating, are not appreciably affected by the sulfur content of the charging stock. In other words, a switch can be made from extremely low-sulfur to high-sulfur crude without changing the treating equipment. The West Texas crudes, for example, are so high in sulfur that many of the older processes, such as doctor sweetening and copper sweetening, fail miserably in processing them.

Some of you may already be aware of the Isoforming process, which is used to improve the octane number of thermally-cracked gasolines or of blends of thermally-cracked and straight-run gasoline. This process is carried out in a similar manner to catalytic desulfurization, and was developed to overcome, to a large degree, the two principal disadvantages of catalytic desulfurization of cracked gasoline, or cracked gasoline in blends with straight-run. In the Isoforming process these disadvantages, polymerization and catalyst coking, are minimized by employing an active catalyst at extremely high space velocity, so that the desired reaction is completed and the material removed from contact with the catalyst before the polymerization and catalyst coking reactions can take place to any great extent. Of greater importance than the actual octane-number improvement that Isoforming gives, is an improvement in the blending octane number. Actual clear octane-number improvement may be as high as 3 to 6 points, depending on the octane number and bromine number of the charge while blending octane-number improvement may be as much as 10 points; depending, of course, upon the properties of the other components of the blend. Isoforming effects some desulfurization, though perhaps not as much as catalytic desulfurization, and this, no doubt contributes to the improvement in octane number; however, it is felt that the principal advantage is in the isomerization that takes place.

Optimum results in Isoforming are obtained at the lowest practical operating pressure, but high temperatures, in the order of 950° F., are used. Since some carbon is formed on the catalyst, about 0.1 to 0.2 percent by weight of the charge, regeneration is required. Catalyst regeneration is not difficult as the amount of catalyst in the plant is small. A 1000-barrels-per-day plant uses about 1400 pounds of catalyst in two vessels, which are alternately on process and regeneration, and only 10-20 pounds of coke is burned per hour. Catalytic desulfurization units by comparison require 10,000 to 20,000 pounds of catalyst for 1000-barrels-per-day charge. Process loss—gas, polymer, and catalyst deposit amounts, on Isoforming, to 2 to 4 percent.

This process is competitive with Unisol treating on some cracked gasolines having an appreciable mercaptan content, for although it costs considerably more to install, there is often more to be gained. Unisol will not show much improvement on low-mercaptan gasolines, while Isoforming may show its greatest improvement on this type of stock. On the other hand, Unisol treating of some high-mercaptan gasolines may give leaded octane improvements nearly as great as Isoforming will give.

Strictly speaking, Isoforming is not considered a desulfurization process, but is mentioned in this paper because it is competitive with treating processes, and from a standpoint of its functional place in refinery operations and the capital investment involved, it can be placed in this general category.

It is hoped that the foregoing will be an incentive to further study of these problems and will offer a laboratory approach to aid in solving them.

REFERENCES

Moriarty, F. C., "Mercaptans," presented before regional technical meeting, Western Petroleum Refiners Association, Shreveport, La., October 30, 1942.

Ball, John S., "Determination of Types of Sulfur Compounds in Petroleum Distillates," U. S. Bureau of Mines Report of Investigations 3591, December, 1941.

Happel, John, and Cauley, S. P., Socony-Vacuum Oil Company, "Significance of the Doctor Test for Gasoline." Presented before midyear meeting, division of refining, American Petroleum Institute, Fort Worth, Texas, May 30, 1940. Published, Petroleum Refiner, June, 1940.

THE Synthine PROCESS

III. PRODUCTS, BY-PRODUCTS, AND SPECIAL TOPICS

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and
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AS HAS BEEN pointed out in the earlier articles of this series, the catalytic hydrogenation of carbon monoxide can be made to yield a wide range of organic compounds, depending upon the choice of reaction conditions and the catalyst employed. From the synthesis of methane, by Sabatier and Senderens[232] in 1902, the successful production of higher hydrocarbons and their oxygenated derivatives by the Badische Anilin and Soda Fabrik[166] in 1913, and the early work of Fischer and Tropsch,[49] dating from 1923, techniques have been evolved which makes possible (though not always economically feasible) the production of aliphatic hydrocarbons, alcohols, and other compounds, such as acids, ketones, esters, ethers, etc., of almost any chain length, degree of saturation, and (only recently) straight-chain, branched-chain, or cyclic structure.

Partly because the ordinary synthesis yields reaction products in which fuel-range hydrocarbons predominate, and partly because national programs for self-sufficiency in petroleum have dictated such a course, widespread interest in the Synthine process has centered around its ability to produce gasoline, diesel fuel, and lubricants. However, the synthetic chemical possibilities inherent in the process give it a significance much greater than that which it would possess if it produced only substitutes for petroleum. Thus, future developments may find the Synthine process being conducted primarily for one or more of the following purposes: (1) to produce maximum quantities of petroleum substitutes, with synthetic chemicals as by-products; (2) to yield large quantities of both petroleum substitutes and synthetic chemicals, neither class being relegated to by-product status; or (3) to produce mainly specialty synthetic chemicals, with fuels and lubricants in the role of by-products. The economic forces of supply and demand, in addition to the effect of changing technology, will dictate the future course of development. Since Synthine economics and current developments will be discussed at some length in the concluding article of this series, it must suffice for the present to review the products obtainable from the synthesis and the processes by which the primary synthesis products may be converted into more valuable and useful materials.

Primary Products

The primary products of the normal (low pressure) Synthine process consist almost exclusively of straight-chain paraffinic and mono-olefinic hydrocarbons. Aromatics and naphthenes ordinarily are present in only negligible amounts. Depending upon the reaction conditions and the catalyst, the yield of oxygenated organic compounds may range from almost zero to several percent.[193]

The hydrocarbons produced in the commercial, cobalt-catalyzed synthesis range from methane to hard waxes with average molecular weights of about 2000.[216, 331, 340, 341] With a ruthenium catalyst, products having molecular weights as high as 23,000 have been obtained.[327]

Depending upon the type of operation, somewhere between 10 to 15 percent of the total product consists of methane. In the two-stage, normal-pressure synthesis, the methane production amounts to 14 or 15 percent. In the three-stage, medium-pressure process (150 psig), the conversion to methane may be reduced by feeding a synthesis gas fairly low in hydrogen to the first stage and increasing the hydrogen-to-carbon monoxide ratio in the later stages. When this procedure is followed, the methane production may be reduced to about 10 percent, with a consequent increase in the yield of higher hydrocarbons.[26, 302]

The "synthetic crude" obtained from the Synthine process is exceedingly peculiar in one respect: it contains no fractions which possess lubricant properties. This is not surprising, however, considering the lack of cyclic compounds, but it does necessitate further treatment of the products if a complete synthetic fuel-lubricants program is desired. A number of methods for preparing synthetic lubricants from Synthine products are discussed later in this article.

Product Distribution

Synthine "crude" from the atmospheric-pressure synthesis consists of about 13 percent LPG, 52 percent gasoline, 26 percent diesel oil, and 9 percent paraffin wax. Similarly, the primary product from medium-pressure operations contains approximately 7 percent LPG, 38 percent gasoline, 30 percent diesel oil, and 25 percent wax.[324]

Fischer[193] has stated that the optimum yield from the single-pass, atmospheric synthesis over cobalt catalyst is about 9.7 pounds of methane and heavier products per 1000 cubic feet of *ideal* synthesis gas.

Table 1 shows distribution of the fractions in the C_3-and-higher primary product.

TABLE 1

Product Distribution—Single-pass, Atmospheric Synthesis[180]

PRODUCT	Percentage by Weight of Total	Percentage Olefins by Volume
C_3-C_4 fraction	8	55
C_5-300° F. fraction	46	45
300° F-390° F. fraction	14	25
390° F.-600° F. fraction	22	10
Wax from oil	7	Melt. pt. 120° F. (approx.)
Ceresin from catalyst	3	Melt. pt. 190° F. (approx.)

The prewar, German, two-stage commercial synthesis over cobalt catalyst is said to have resulted in the liquid product distribution shown in Table 2.[331] Since the second stage of this process was operated at pressures above atmospheric (up to 150 psi), a higher yield of wax was obtained than in Fischer's experiments at atmospheric pressure.

TABLE 2

Primary Products from Prewar Two-Stage Snythesis[331]

PRODUCT	Boiling Range	Specific Gravity	Percentage by Weight of Total		Percentage Olefins by Volume	
			1st Stage	2nd Stage	1st Stage	2nd Stage
C_3-C_4 fraction	.....	.....	5	2	50	25-30
C_5-300° F. fraction	85° F.-300° F.*	0.66	26.5	8	35-40	20
300° F.-575° F. fraction	200° F.-575° F.*	0.74	26.5	11	12	12
Paraffin Wax	.....	0.85	.....	21	.....	.....

* The overlapping boiling ranges of the liquid fractions resulted from the method of recovery; the lighter fraction was adsorbed on activated charcoal after condensation of the heavier fraction.

The "normal pressure" (4 psig), two-stage synthesis employed by many of the German plants during the late war yielded from 8.5 to 9.5 pounds of C_3 and higher hydrocarbons per 1000 cubic feet of ideal synthesis gas. As mentioned, methane constituted about 14-15 percent of the conversion. Another 15 percent of the total product consisted of the C_3-C_4 cut, of which approximately 49 percent was propane, 16 percent propylenes, 9 percent butanes, and 26 percent butylenes. Product distribution in the C_5 and higher fractions was as follows: 320° F. end-point gasoline, 50 percent; 320° F.-450° F. diesel oil, 20 percent; 450° F.-600° F. heavy oil, 20 percent; and wax, 10 percent.[27, 331]

Operation of the Synthine process at medium pressures of about 150 psig results in much higher wax yields and in smaller quantities of hydrocarbons in the gasoline boiling range. As mentioned in the second article of this series, Ruhrchemie A.-G.'s director has stated preference for this process because valuable synthetic chemicals can be made from the wax.[26] Typical yields of primary products from three-stage operation of the medium-pressure synthesis are given in Table 3.

TABLE 3

Product Distribution—Three-stage, Medium-Pressure Synthesis[26]

PRODUCT	Percentage by Weight of Total	Percentage Olefins by Volume
C_3-C_4 fraction	10	40 (13% of C_4's are iso)
C_5-340° F. fraction	25	24 (about 45 O.N., MM)
340° F-535° F. fraction	30	0
535° F.-640° F. fraction	20	Soft wax
Hard wax	15	M.P. about 195° F.

Much experimentation has been directed toward increasing the percentage of olefins in Synthine primary products. This work has been intended to serve the double purpose of increasing the octane number of the gasoline and of producing increased yields of unsaturates which are amenable to subsequent conversion operations, such as the OXO process, polymerization, alkylation, and sulfuric acid absorption followed by hydrolysis to alcohols. For example, gas recycle over cobalt catalysts has been found to yield the following products[26, 302]:

C_3-C_4	8%	(60-65% olefins)
Gasoline	30%	(60-65% olefins)
Middle Oil	28%	(40-65% olefins)
Wax	34%	(small % olefins)

Methods of increasing the olefin content of primary products have been discussed in some detail in the second article of this series.

I. G. Farbenindustrie A.-G.'s hot-gas-recycle process, over sintered iron catalyst, also described in the preceding article in this series, is likewise designed to produce more valuable primary products.[26, 181] This process yields about 20 percent methane (plus some ethane), 24 percent C_2-C_4's, 38.5 percent gasoline (7 percent alcohols), 11 percent gasoil (4 percent alcohols), 1 percent paraffin wax, and 5.5 percent of alcohols which are dissolved in the reaction water. The C_2-C_4 cut contains about 8 percent ethylene, 3 percent propane, 9 percent propylene, 2 percent butane, and 8 percent butylene. Moreover, 75 percent of the C_4 fraction is said to consist of isobutane-isobutylene.[313A]

By circulating a liquid fraction of the reaction product over a fixed bed of the same sintered iron catalyst (in order to remove the heat of reaction), the C_3-C_4 cut is said to amount to 16 percent (85 percent olefins); the gasoline fraction to 40 percent (50 percent olefins); the gasoil to 20 percent (25 percent olefins); paraffin wax to 20 percent; and alcohols (mainly C_1 and C_2) to 4 percent.[302] Interesting enough, very similar yields are reported elsewhere[208] without mention of a liquid medium.

Product Recovery

In Germany at least, the C_3 and higher products of the synthesis are separated from the residual gas by first allowing the heavier products to condense and then recovering the lighter products by adsorption or absorption.

A common method in normal-pressure plants is to condense the heavier products (all but the light gasoline and C_3-C_4's) by direct contact with water in packed scrubbing towers, followed by adsorption of the light gasoline and C_3-C_4 hydrocarbons on activated charcoal.[27, 147] In a typical German, two-stage, normal-pressure plant, each stage was equipped with a charcoal adsorption unit. Each unit consisted of seven towers, normally worked as follows: two towers adsorbing, one tower steaming, two towers drying, and two towers cooling. The time involved in each step was approximately as follows: adsorption, 40 minutes; steaming, 20 minutes; drying, 40 minutes; and cooling, 40 minutes.[27]

In the medium-pressure synthesis, the lighter products may be absorbed in oil, usually a fraction of the synthesis product.[147] Since only partial recovery of the C_3-C_4 fraction was attained, however, oil-scrubbing was not considered by the Germans to be highly satisfactory.[310] The more common procedure involved the use of activated carbon at atmospheric pressure. The Linde organization reportedly advocated recovery of all products, including the C_3-C_4 fraction, by cooling under pressure; however, it was stated that this had not been tried commercially.[310]

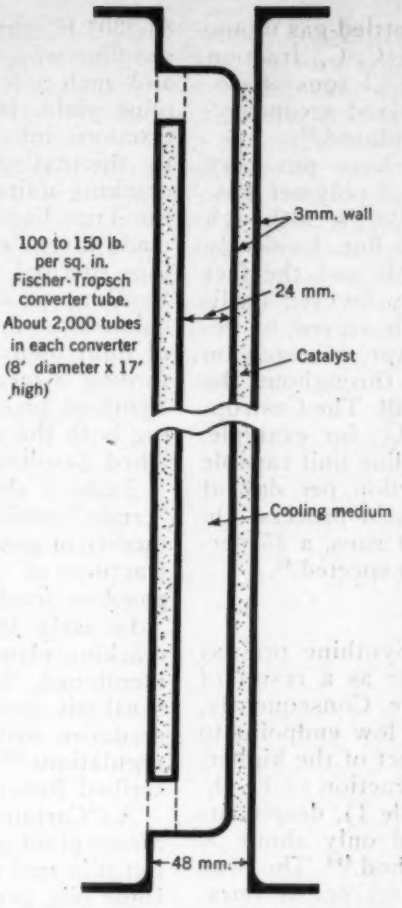
The carbon dioxide content of the gas which re-

mained after removal of the C_3 and higher products was reduced by use of the Alkazid process.[310] As mentioned in Article I, this process, which involves the use of an alkaline organic compound, was used in some German Synthine plants to remove hydrogen sulfide from the synthesis gas.[26, 99, 123]

Residual Gas—Methane

After recovery of the C_3 and higher products, the residual gas consists mainly of methane, unconverted synthesis gas, carbon dioxide, and nitrogen, and also contains small amounts of ethane and ethylene. The relative proportions of these individual gases vary considerably with the type of operation and the reaction conditions. In one plant, the residual gas from the two-stage, normal-pressure synthesis was found to contain 30.9 percent methane, 18.0 percent hydrogen, 10.5 percent carbon monoxide, 20.3 percent carbon dioxide, 18.5 percent nitrogen, and 1.6 percent ethane-ethylene. The heating value of this gas was about 395-425 Btu per cubic foot. In some plants, part of the dry gas from the charcoal adsorption step was returned to a coke-oven-gas cracker for reconversion of its methane content to synthesis gas, while the balance was burned as a lean fuel gas.[27] In others, the entire gas was simply used as fuel for heating in such other plant operations as gas production and purification.[27]

The fact that from 10 to 15 percent of the synthesis gas is converted to methane in the Synthine process makes it advisable, from the economic point of view, to utilize the methane thus produced for as thermally useful a purpose as is possible. The "upgrading" of manufactured gas is one such use; in fact, the gas works of the city of Leipzig, Germany, was installing a Synthine plant with this purpose in mind when the war ended.[314] This plant, which produced 5,826,150 cubic feet of coke-oven gas and 8,121,300 cubic feet of water gas per day, planned to mix 2,612,940 cubic feet of the coke-oven gas and 5,155,260 cubic feet of the water gas to make 7,768,200 cubic feet of synthesis gas, which was then to be fed to the Synthine plant. In addition to the highly-desired liquid and solid Synthine products, about 3,884,100 cubic feet of residual gas would have been obtained, which, when mixed with the 3,213,210 cubic feet of coke-oven gas and 2,966,040 cubic feet of water gas, which were not to be utilized for synthesis gas, would have supplied the city with 10,063,350 cubic feet per day of gas having a heating value of about 450 Btu per cubic foot and a density of 0.0394 pound per cubic foot. The percentage compositions of the gases mixed and the composition of the finished city gas may be seen in Table 4.


100 to 150 lb. per sq. in. Fischer-Tropsch converter tube. About 2,000 tubes in each converter (8' diameter x 17' high)
3mm. wall
24 mm.
Catalyst
Cooling medium
48 mm.

Courtesy H. H. Storch, U. S. Bureau of Mines.

Section of middle-pressure Ruhrchemie Synthine reactor tube.

The C_3-C_4 Fraction

The C_3-C_4 fraction generally constitutes about 13 percent of the crude liquid product obtained from the normal-pressure synthesis and about 7 percent of that produced in medium-pressure operation.[324] This fraction is of special interest in any consideration of the Synthine process because of the prospects it offers for the manufacture of high-octane polymer or alkylate gasolines. Synthetic alcohols may also be produced from the olefins by sulfuric acid absorption and subsequent hydrolysis or by the OXO process. The propane and normal butane naturally possess value as LPG fuels. However, since both economics and wartime demands favor production of hydrocarbons more readily adaptable to further synthesis, much effort has been devoted toward producing greater quantities of olefins and iso-compounds in this fraction.

The methods of raising the olefin content have already been discussed earlier in this article, and the "Iso-Synthesis" process was treated in Article II of this series; it is obvious that the quantities of alkylate and/or polymer gasoline obtainable from the Synthine process are functions of the isobutane-isobutylene and the olefin content of this fraction.

It may be of interest to review here the uses to which the Germans have put the C_3-C_4's produced in their commercial processes. In some of the commercial plants, the C_3-C_4 cut was absorbed in sulfuric acid and hydrolyzed to alcohols, some incidental polymer being also formed and used for blending in motor fuel. In one typical, normal-pressure plant, this fraction was contacted for about one hour with 58° Be. sulfuric acid at about 110° F. and 150-220 psi. After a 30-minute settling period, the ester-acid bottom layer was drawn off and contacted with water at atmospheric temperature and pressure. This caused separation into a relatively small upper layer of polymer and a larger lower layer of ester. The ester layer was hydrolyzed in a four-stage system by heating with open steam at an absolute pressure of about 3 psi. The temperatures in the successive stages were as follows: Stage 1, 160-175° F.; Stage 2, 175-190° F.; Stage 3, 190-203° F.; and Stage 4, 203-220° F. The hydrolyzed product contained alcohols in about 50 percent concentration, while the acid was reduced to about 25 percent H_2SO_4. The upper layer removed from the primary (sulfuric acid) contactor contained the paraffinic C_3-C_4's and some polymer. All products were caustic washed, the polymer from both the upper and lower primary layers was blended in motor fuel, and the unreacted (paraffinic) C_3-C_4

TABLE 4
Upgrading Manufactured Gas With Synthine Residual Gas[314]

Analysis, Vol. Percent	Coke-Oven Gas (3,213,210 ft.³/D)	Water Gas (2,996,040 ft.³/D)	Residual Gas (3,884,100 ft.³/D)	Resultant City Gas (10,063,350 ft.³/D)
CO_2	2.4	5.0	8.1	5.4
C_nH_m	1.2	....	1.0	0.8
O_2	0.4	....	....	0.1
CO	5.7	38.0	21.3	21.2
H_2	59.0	52.0	37.5	48.6
CH_4	27.8	0.3	23.6	18.1
N_2	3.5	4.7	8.5	5.8

fraction was compressed for use as bottled-gas motor fuel. From 26-28 tons per day of C_3-C_4 fraction (about 30 percent olefins), about 2.0-2.1 tons of isopropyl alcohol, and 3.2-3.5 tons of mixed secondary- and tertiary-butyl alcohols were produced.[27]

The Germans do not appear to have put very strong emphasis on the production of polymer gasoline or alkylate from Synthine C_3-C_4's, although they were somewhat active along this line. Evidently the strong demand for C_3-C_4 alcohols and the fact that coal hydrogenation was strongly favored (politically) for gasoline production both served to deemphasize this development. However, research on the "Iso-Synthesis" was continued throughout the war, and polymer plants had been built. The Castrop-Rauxel plant of Klocknerwerke A.-G., for example, was found to possess a polymer gasoline unit capable of processing 25 tons of C_3-C_4 fraction per day at about 2950 psi. by the phosphoric acid process. On the basis of 10 days of experimental runs, a 45 percent yield of polymer gasoline was expected.[65]

Synthine Gasoline

Gasoline from the conventional Synthine process is notoriously low in octane number as a result of its straight-chain, paraffinic structure. Consequently, these gasolines are usually cut to a low endpoint to maximize, as far as possible, the effect of the higher-octane lower ends. The C_5-300° F. fraction of Fischer's atmospheric synthesis (see Table 1), despite its 45 volume-percent of olefins, tested only about 55 octane number by the Motor Method.[193] The lead susceptibility, however, was high, 0.5 cc. of tetraethyl lead raising the rating to 72 octane number.

Ruhrchemie's prewar, two-stage process yielded an 85-285° F. gasoline of 62 octane number or an 85-230° F. gasoline of 67 octane number.[331] Such gasoline was, of course, too volatile for ordinary use, and such a low cut point greatly reduced the gasoline yield. In order to convert the higher boiling fractions into usable gasoline, the company turned to thermal cracking, installing True-Vapor-Phase cracking units at two of its plants.[331] The choice of the True-Vapor-Phase process was said to have been made after "exhaustive tests" of the merits of various thermal cracking processes in the treatment of Synthine products. The conditions of cycle-gas circulation in the T-V-P process favor polymerization of light olefins, a fact which was recognized as affording a means of converting the C_3-C_4 cut of the Synthine product to polymer gasoline, thus increasing both the yield and the octane number of the finished gasoline.

Table 5 shows the results of cracking Synthine "crude," while Table 6 gives data on the yields and quality of gasolines prepared by cracking the heavier fractions of the crude and blending with the light gasoline fraction collected by charcoal adsorption.

In early 1938, Ruhrchemie was not utilizing its cracking plants to upgrade Synthine gasoline as just mentioned, but was instead blending low-octane synthetic gasoline with benzol and alcohol in accordance with the then-existing German motor-fuel regulations.[331] Martin[322] and Davies[304] have also described Ruhrchemie's thermal cracking installations.

A "Carburol" cracking plant was erected at the Moers plant of Steinkohlen-Bergwerk Rheinpreussen, but it is said that it never was used to crack the Synthine oils, presumably because they were considered more valuable as diesel fuel than as cracking stock.[27]

Starting with a liquid Synthine product boiling between 113 and 702° F., Egloff, Nelson, and Morrell[305] obtained 84 volume percent (based on charge) of 66-octane gasoline by subjecting the entire fraction to distillation, thermally reforming the naphtha, thermally cracking the bottoms, and catalytically polymerizing the cracked gases. The yields from the various steps are shown in Table 7. The octane number of the gasoline and the yield based on synthesis gas charged could, of course, be considerably raised by also polymerizing the C_3-C_4 fraction of the Synthine product.

According to Velde,[334] Ruhrchemie later developed a catalytic reforming process in which the gasoline fraction was passed in the vapor phase over a special (unidentified) catalyst at a temperature somewhat below that at which appreciable cracking would take place. The vapors from this step were then cooled and passed over the same catalyst at a lower temperature. Increases of 8-24 points in octane number were claimed for the process. It was believed that this improvement was the result of an isomerization of the charge which included both branching and a shift in the position of the double bonds within the olefins, displacing them from the ends of the molecule to positions nearer the middle, thereby increasing the antiknock rating.[310] Illustrative of the effect of olefin content on the reforming ability of the process was the treatment of a gasoline of 44 octane number which contained 35 percent olefins; this was upgraded to 52 octane number, while another gasoline of 41 octane number, containing 55 percent olefins, was raised to 61 octane number by similar treatment.

Fischer and Weinrotter[308] have cracked Synthine heavy oils with electrically-heated, platinum-wire spirals at low-glow temperatures. Over 50 percent

TABLE 5
T-V-P Cracking of Synthine Crude Oil[331]

CHARGE STOCK	Reduced Crude			Untopped Crude	
Specific Gravity	0.769			0.725	
Cracked Gasoline:					
Yield, percent by weight	81	75.5	65.2	70.6	65.2
Yield, percent by volume	88	81.8	73	72	68.3
Specific Gravity	0.7079	0.7096	0.6876	0.7114	0.6920
End-point, °F.	392	386	333	386	320
Octane number, M.M.	62	68	75	67	73
TEL to raise to 80 O.N., cc./gal.	.....	3.5	1.3	3.7	1.7

TABLE 6
Yield of Cracked and Blended (380° F. E.P.) Synthine Gasoline[331]

Percent by Weight of Total Liquid Products	Run 1	Run 2	Run 3
Before Cracking:			
Charcoal-adsorbed gasoline (unstabilized)	42.5	40	30
Cracking stock	57.5	60	70
Total primary product	100	100	100
After Cracking:			
Charcoal-adsorbed gasoline (stabilized)	40	37.5	28
Cracked gasoline (stabilized)	44	44.5	47
Total blended gasoline	84	82.0	75
Octane number (M.M.) of finished blend	63	68	70

TABLE 7
Processing Synthine Liquid Product[305]

PRODUCT	Yield, Volume Percent on Charge
Light Gasoline (cut at 97-241° F., 68 O.N.)	29.1
Reformed gasoline (from 219-523° F. naphtha)*	26.8
Cracked gasoline (from bottoms)	22.6
Polymer gasoline (from cracked gases)	5.8
	84.3

* Octane number of naphtha fraction before reforming was 4.

of the oils can thus be cracked, with up to 90 percent of the cracked product consisting of unsaturated hydrocarbons. A number of references to similar earlier work of Fischer and his co-workers are given by these authors.

Russian investigators[209] have experimented with the aluminum chloride cracking of fractions of the Synthine products. The products boiling above 470° F. and including the solid fraction require the use of approximately 20 percent of aluminum chloride for good cracking results. The solid fraction, boiling above 570° F., is said to require only 10 percent of aluminum chloride for satisfactory results. Maximum yields, however, are claimed for 15 percent $AlCl_3$, about 48 percent gasoline thus being produced. The 70-300° F. gasoline is said to be composed almost exclusively of isoparaffins. The octane number of the 70-122° F. fraction, which contains C_5's and C_6's, is said to be about 88; that of the 122-212° F. fraction, 73; and the rating of the entire gasoline cut, 79.

Sergienko[330] has reported experiments on the cyclization of the heptane-octane and the nonane fractions of Synthine products. These experiments were carried out at about 885° F. over alumina-chromia-cobalt oxide or chromia-cobalt oxide catalysts. Aromatics constituted more than 50 percent of the product, while cracked products amounted to about 5-10 percent and aliphatic unsaturates to about 4-12 percent.

According to Director Martin, Ruhrchemie was constructing a catalytic cracking plant to produce C_3-C_5 olefins from C_7 and higher Synthine fractions. These olefins were to be used to make polymer gasoline. Pilot-plant tests indicated that the "Granosil" catalyst (acid-treated clay) would have a life of 6-8 weeks, after which it would be discarded. During use, the catalyst required carbon removal (by oxidation) at intervals of 8 to 10 hours. This catalytic cracker was about 60 percent complete when construction was abandoned in mid-1944.[310]

As mentioned, the raw gasoline fraction from I.G.'s hot-gas-recycle process over sintered iron catalysts contains about 7 percent of alcohols. In the raw state, this fraction has an octane number of 68-70 by the Research Method. Passage of this gasoline over alumina at 750-840° F. for dehydration of the oxygenated compounds, followed by refining over fuller's earth at 355-390° F., raises its rating to about 84 octane number by the Research Method and 75-78 octane number by the Motor Method. The refined gasoline is said to contain about 70 percent olefins.[302] This gasoline appears to be somewhat similar to that produced by the Hydrocol process, which apparently is a fluid catalyst process using "cheap, rugged, iron catalyst. * * * The finished gasoline produced by Hydrocol with a Reid vapor pressure of 10 pounds has a clear octane number of 80 CFRM or 88-90 CFRR."[314A]

Since the synthesis gas is (at present) made as nearly sulfur-free as possible prior to the synthesis reaction, and since practically no diolefins are formed in the synthesis, raw Synthine gasoline normally requires neither desulfurization nor treatment to improve its gum stability. The only treatment needed (short of octane number betterment) is a light alkaline wash to remove organic acids.[140]

According to Dannefelser,[303] practically no gum formation takes place during prolonged storage of Synthine gasoline, and the mono-olefin content (30-40 percent in his samples) remains unchanged. When the gasoline is stored in large batches, peroxide formation is said to be negligible. However, the octane number of a small sample stored for 15 months in a sealed can was lowered by three units. Orthocresol has been suggested as a peroxide inhibitor.

An interesting method for predicting the octane number of stabilized Synthine gasoline from its "olefin index" and "vaporizability" has been advanced by Hammerich.[312] For raw Synthine gasoline, the determination has been said to deviate by less than one octane number from the rating experimentally obtained by the CFR Research Method. However, any treatment of the gasoline, such as reforming or blending with other fuels, invalidates the relationship.

Synthine Diesel Oil

Synthine fractions of the diesel oil boiling range usually possess exceptionally high cetane numbers. In fact, in the conventional, cobalt-catalyzed synthesis, cetane numbers of 100 or more have been obtained. A typical diesel oil fraction might boil from 390-680° F. and have a specific gravity of about 0.769, a hydrogen content of 15.2 percent, and a heat of combustion of 18,900 to 20,300 Btu per pound.[132] Synthesis procedures which are designed to produce more olefins naturally yield diesel fractions of lower cetane number; however, even these fractions have higher cetane numbers than are common in diesel fuels from other sources.

The Synthine fraction actually used for diesel fuel by the Germans during the war had a much lower boiling range than that just mentioned. Their "SDK" fuel had a boiling range of 310-485° F., a density of 0.743-0.749, a solid point of -36 to -42° F., and a flame point of 80-120° F. This fuel, which had a cetane number of 75-78, is believed to have consisted entirely of a Synthine fraction with (probably) a pour-point depressant added.[27]

The motivation behind the German use of such low-boiling fractions for diesel fuel is not entirely clear from the available information. However, there appear to have been several significant factors involved in such use. As mentioned, Synthine gasoline was cut to a low end point to attain as high an octane number as possible. The strong demand for diesel fuel (and possible lack of octane-improving facilities) prompted them to add the heavier gasoline to the diesel fraction, thus lowering the latter's initial boiling point. The fuel was made even lighter by appropriation of the heavier oils for conversion to "Mersol" detergents.[65] It has also been indicated that straight Synthine fractions, in spite of their high cetane numbers, do not make the most satisfactory diesel fuels and that blending Synthine fractions with petroleum oils or oils obtained by coal distillation or hydrogenation yields fuels of superior combustion characteristics.[297]

Some amplification of this last point might be desirable here. A recently published article[320] has reported the results of combustion studies on a series of fuels of narrow distillation range and 40-90 cetane number. The paraffinic, high-cetane fuels were found to produce more black smoke (indicative of fuel waste) and to exhibit a lower rate of pressure rise and a lower peak cylinder pressure during combustion. It is believed that highly paraffinic fuels, being less refractory cracking stocks, may be more susceptible to pyrolysis in the combustion chamber, producing more carbon, some of which emerges from the exhaust as black smoke. The low rate of pressure rise with Synthine diesel fuel may be raised by blending it with aromatic fuels (such as tar oils)

TABLE 8

Comparison of Synthine, Tar Oil, Synthine-Tar Oil, and Petroleum Diesel Fuels[297]

	Synthine	Tar Oil	MIXTURE		Petroleum Gasoil
			Untreated	Treated	
Specific Gravity	0.760	1.060	0.862	0.865	0.857
Color	Water Clear	Black	Brown Opaque	Yellow Translucid	Yellow
Flash Point (P-M), °F.	120	235	158	158	194
Pour Point, °F.	—4	32	—4	—4	—22
Boiling Index, °F.	420	500	500	500	525
Conradson Carbon, Percent	0.03	0.26	.....	0.004	0.05
Sulfur, Percent	0.00	0.80	0.40	0.10	0.5
Low Heat Value, Btu/lb.	18,800	17,850	.....	18,600	18,600
Hard Asphalt, Percent	0.00	2.5	0.46	0.03	0.06
Insoluble in Benzol, Percent	0.00	4.8	0.87	0.05	0.11
Cetane Number	96	20	60	60	50

which possess characteristically high rates of pressure rise.[333]

Competitive tests with a high-cetane Synthine fraction and a 47-cetane petroleum cut showed that use of the Synthine fraction entailed an increase in fuel consumption of about 5 percent (based on equal heat value) and an increase in exhaust gas temperature of some 25 percent.[297]

Blending of Synthine product with low-cetane fuels from other sources, then, both improves the combustion characteristics of the former and the cetane (ignition characteristic) of the latter. Typical German blends are said to have contained 40-45 percent of Synthine fraction and 55-60 percent of either a petroleum gasoil or a fraction produced by distillation or hydrogenation of coal. These blends, however, contained asphalt gum and carbon-forming materials which tended to clog engine injection systems, and various processes had to be developed to refine them. One method consisted of treatment with gaseous sulfur dioxide at atmospheric pressure. This process is said to have been inexpensive, since the sulfur dioxide was recirculated, and makeup was small.[27, 297] Kolbel[318] has discussed the blending of Synthine product with coal hydrogenates, distillates, and extracts. He has claimed that mixtures containing 40-55 percent Synthine oil possess cetane numbers of 65-85 and compare favorably with petroleum fuels in ignitability, resistance to carbon formation, and completeness of combustion. Table 8 compares the inspections of a Synthine fraction, a tar oil fraction (from coal distillation), a blend of the two, and a typical petroleum gasoil.

The process by which the heavier diesel oil fraction (445-605° F.) was converted to synthetic detergents is discussed in a later section. However, it might be pointed out that Martin (Ruhrchemie) considered such chemical developments as the logical future use of the Synthine process (for Germany, at least) and felt that its use for fuel production was economically unsound, in spite of the premium diesel fuels it can provide.[310] The fact that such chemical production was conducted during the war, when diesel fuels were in critical demand, may illustrate his point, although such an assumption should be examined in the light of other factors; namely, that soap and detergent supplies were likewise extremely short and that Nazi party politics (reportedly) influenced the German fuel policy in favor of coal hydrogenation over the Synthine process.

It is interesting to note[314A] that the diesel oil to be produced in this country at the proposed Brownsville, Texas, plant of Carthage Hydrocol, Inc., will have "a gravity of about 38° API, a cetane number of 45-50, and a pour point below 0° F." Presumably, these are the properties of the diesel oil cut of a Synthine "crude" produced by a fluid catalyst process utilizing "cheap, rugged, iron catalysts." No further details are available at present.

Paraffin Waxes

The Synthine product remaining after removal of the diesel oil and lighter fractions consists of waxes of various melting points and molecular weights. A hard wax is also recovered from the catalyst by extraction with gasoline fractions.[310] As previously stated, the wax yield and the type of wax obtained is dependent upon the reaction conditions (particularly the pressure) and the catalyst employed in the synthesis. Higher pressures favor wax production, and the use of ruthenium catalysts results in large yields of waxes which possess exceptionally high average molecular weights.

Synthine waxes consist of a mixture of normal- and iso-paraffins; i.e., they are aliphatic in nature, while petroleum-derived waxes and those obtained from coal tars contain varying (usually small) quantities of cyclic compounds.[309]

The quantities of wax produced in various types of Synthine operations with conventional cobalt catalysts may be seen by reference to Tables 1, 2, and 3. The melting points of these waxes range from 120° F. to 240° F., and they have molecular weights as high as 2000.[316, 331] Koch and Ibing,[316] in 1935, published a quite detailed study on the composition of Synthine waxes from the cobalt-catalyzed synthesis. When ruthenium catalysts are used, as much as 66 percent of the total product may consist of solid paraffins. The reaction at 380° F. and 1500 psi yields about 6.2 pounds of wax and 3.1 pounds of liquid per 1000 cubic feet of synthesis gas.[227] Pichler and Buffleb[327] used solvent extraction to separate the solid product from the ruthenium synthesis (at 14,700 psi). The physical properties of the fraction which they obtained are shown in Table 9.

In their commercial plants, the Germans separated the Synthine waxes into soft paraffin, slab paraffin, and hard paraffin by fractional distillation, pressing, and sweating.[310] The crude paraffin was first topped at about 605° F. to remove diesel oil components. The residue was then subjected to vacuum distillation and cut at about 840° F. The bottoms consisted of hard paraffin with a melting point of approximately 195° F. The distillate was allowed to cool, and the slab paraffin components (melting at 124-128° F.) were removed by pressing and sweating. The remainder of the distillate was soft paraffin with a melting point of 85-95° F.

Some experiments had been conducted on solvent extraction of the wax product in order to separate the three types just mentioned. Acetone and gasoline were considered promising solvents, but the work was not very far along when the war ended, and no definite process had been developed.[310]

The Germans converted most of the softer Syn-

TABLE 9

Solvent Extraction of Wax from Ruthenium Synthesis at 14,700 psi.[227]

EXTRACTION CONDITIONS				PHYSICAL PROPERTIES				
				Density			Viscosity, cs.	
Solvent	Temp. °F.	Percent Soluble	Melt. Pt. °F.	20° C.	150° C.	Mol. Wt. (Av.)	150° C.	180° C.
n-Pentane	90	30-33	123-135	.....	.....	.....	.....	.....
n-Hexane	155	14-17	200-204	.....	0.765	760	6	4
Synthine cut	194	14-16	250-252	0.966	0.778	1,750	29	17
n-Heptane	208	20-25	264-266	0.978	0.783	6,750	870	410
Synthine cut	250	12-15	270-273	0.980	0.786	23,000	35,600	15,600

thine waxes to fatty acids which then were used in the production of soaps and edible fats.[302, 311] A part of these waxes were also used for the preparation of lubricating oils.[318] The hard wax was sold for use in ceresin. It has been stated that the harder Synthine waxes have excellent electrical properties.[140] However, Martin has said[306] that there was only a very small market in Germany for Synthine hard wax and it will not be a very important product until new uses for it are discovered. It has even been considered economic to crack Synthine wax to produce gasoline.[140] The chemical processing of Synthine waxes to yield soaps, fats, lubricating oils, etc., are covered in the later sections of this article.

Lubricants

As mentioned; no lubricants as such are directly produced by the hydrogenation of carbon monoxide, since the straight-chain paraffins which are predominant products of the usual synthesis do not, *per se*, possess lubricating properties. It is possible, however, that some modification of the process, perhaps through addition of another reactant, may make possible a direct synthesis. One British patent[338] claims the production of paraffin wax and lubricating oil by the catalytic reaction of CO with a large excess of H_2 at 482° F. (below 697° F.) under 750 (above 300) psi pressure in a hydrocarbon medium (such as anthracene oil) that remains liquid under the reaction conditions and in which a catalyst (such as ZnO, MgO, and Fe) is suspended.

Disregarding this possible exception, lubricants have been in general produced from Synthine products by one or more of the following types of synthesis: (1) polymerization of the lower olefins, olefins in the middle oil fractions, olefins produced by the cracking of Synthine wax, or olefins produced by the halogenation of paraffins and subsequent dehalogenation; (2) alkylation of aromatics with long-chain Synthine olefins; (3) chlorination of Synthine wax or heavy oils, followed by direct condensation or the alkylation of aromatics with the long-chain chlorides; and (4) treatment of heavy fractions with a silent electrical discharge, etc. In some cases, synthesis is followed by saturative hydrogenation, in order to increase stability.

The literature on lubricant synthesis in general and synthesis from Synthine products in particular is already voluminous; a literature search[335] reported last year by one of the authors of this series included nearly 600 references, most of them related in some manner to synthesis of lubricants from Synthine products. Since that time, the Office of the Publication Board has released a steady stream of reports[26, 208, 290, 293, 294, 313, 333, etc.] which contain much pertinent data on German developments.

Martin has testified[26] that Synthine lubricating oils were greatly improved in Germany since the war began. The best stock for lubricating oil was reportedly obtained by cracking primary products boiling between 427° and 607° F. or wax with a melting point below 86° F. Such stock had to be filtered prior to cracking in order to remove traces of cobalt left from the Synthine catalyst, since even small quantities introduced undesirable side reactions. A Dubbs unit was used for cracking at temperatures below 930° F. in the presence of steam. Lubricating oil yields of 55 percent were obtained from the cracked product; most of the oil had a viscosity of about 325 Saybolt Universal Seconds at 122° F. and a viscosity pole height of 1.7. Attempts were made to produce higher viscosity oils by operating at lower temperatures.

Atwell and Schroeder[294] have described in detail Rheinpreussen's synthetic lubricating oil plant at Homberg. Synthine middle oil of approximately 482-662° F. boiling range was chlorinated at 176-212° F. until the chlorine content reached 20-25 percent by weight, then reacted with naphthalene at 158°-212° F. in a volume ratio of five to two, in the presence of eight volumes of a Synthine naphtha fraction (as diluent) and a small amount of either metallic Al or $AlCl_3$ catalyst. After sludge separation, neutralization, filtration, and naphtha stripping, the product was vacuum distilled to yield spindle oil and turbine oil as overhead and cylinder stock as bottoms.

The fractions were used straight or in blends as motor oils. While Dr. Albert Meusel, the source of the information, claimed that all products had high viscosity indexes and were resistant to oxidation, Petroleum Board tests on captured stocks (Table 10) did not confirm these statements. Dr. Meusel stated that the Conradson carbon and neutralization number of motor oil blend were increased only slightly by air blowing, but Petroleum Board tests on the summer motor oil shown in Table 10 showed an increase in Ramsbotham coke of 1.73 (from 0.72) upon use of the B. A. M. oxidation test, while the viscosity (at 100° F.) was 2.26 times as great as that prior to oxidation.

A 25-ton-per-day plant near Marseille, France, has been producing lubricants by the following series of steps: (1) the chlorination of highly-paraffinic gasoil (end point, 680° F.) at 194-212° F.; (2) mixing of benzene and dichlorethane at 158° F. in the presence of $AlCl_3$; (3) reaction of the chlorinated gasoil and benzene-dichlorethane at 158° F. in the presence of $AlCl_3$; and (4) termination of the reaction at 230° F. "To make a ton of finished lubes, 600 kg. of gasoil, 600 kg. of benzene, and 160 kg. of dichlorethane are required"; total reaction time is six hours; and "the total quantity of $AlCl_3$ is 10 percent by weight. * * * The present volumetric breakdown of the products is: recycle gasoil, 20 percent; transformer oil, 30 percent; turbine oil, 30 percent; and steam cylinder oil, 20 percent."

The claimed viscosity index of 100 for the lubricating oils is attributed to the chemical constitution of the lubricant, which is a polybenzene with a long, saturated paraffin chain. The oil "is roughly half aromatic and half paraffinic, giving it both a high viscosity index and a low pour point."[290]

The same report describes a pilot plant at Harnes, France, which uses a process developed in Germany to prepare lubricants by the polymerization of a

TABLE 10

Petroleum Board Tests on Captured Lubricants[294]

	Spindle Oil	Turbine Oil	Cylinder Oil	MOTOR OILS*	
				Winter	Summer
Sp. Gr.	0.901	0.928	0.965	0.939	0.938
Vis. 100 °F., S.U.S.	81.5	203.4	8958	754.9	864.4
Vis. 210 °F., S.U.S.	37.0	44.2	244.1	64.0	72.6
Viscosity Index	54.6	50.0	61.0	41.1	67.0
Neut. Val.	<0.05	<0.05	<0.05	<0.05	<0.05
Pour Point	+25° F.	−15° F.	+25° F.	−10° F.	−20° F.
Flash Point (closed)	340° F.	395° F.	525° F.	395° F.	440° F.
Coke No. (Ramsbotham)	0.17	0.24	0.11	0.62	0.72

* The winter grade was supposed to have a viscosity of about 270-300 S.U.S. at 122 °F. and to be a blend of 45 percent cylinder oil, 47 percent turbine oil, and 87 percent spindle oil; the summer grade, a viscosity of 400 S.U.S. at 122° F. and a composition of 49 percent cylinder oil and 51 percent turbine oil.

Synthine gasoline containing 50 percent olefins, produced by lowering the normal H_2/CO ratio of the Synthine synthesis reaction from 2/1 to 1/1 and by raising the reaction temperature. The lubricant synthesis takes five hours in the presence of 3 percent $AlCl_3$; the resulting products are a gasoil, a light lubricant "suitable for cold service, and a heavy lube for ordinary lubrication. * * * The quality of these lubricating oils is not exceptionally good. The 'oiliness' is poor, and the oils apparently oxidize readily."[290] In this connection, it is interesting to note[26] that in some German plants "the oxidation test has been improved by inhibitors, the best one being phenothiazine." Incidentally, Storch[132] reports that the synthesis of lubricants by the direct catalytic polymerization of the olefins produced in the Synthine synthesis has received more attention than synthesis by any other method.

The major portion of the synthetic aviation lubricating oil blending stock produced in Germany during the war was made by the polymerization of ethylene in the presence of $AlCl_3$ ("Standard Oil process and patent"). The ethylene must be of high purity; it is polymerized at about 250° F. in the presence of $AlCl_3$ (containing about 4 percent $FeCl_3$) under 60-100 atmospheres pressure. A commercial yield of 80 percent is claimed, and it is said that the viscosity index may be as high as 120, depending primarily upon the temperature and the time of reaction.[293, 312A] The ethylene was generally obtained by the cracking of ethane or the hydrogenation of acetylene; it can, of course, be obtained from refinery (cracked) gases or by the deliberate cracking of propane, gasoil, etc. Holroyd[213] reports that "the whole secret of the (lubricant) process is the final purification of the ethylene" and that the process "is definitely superior to any corresponding process developed by the Allies."

It is interesting to note, incidentally, that one German process called for the reaction, in the presence of $AlCl_3$, of an olefin polymer and a deasphalted, dewaxed, *but not solvent refined* petroleum lubricant distillate.[315] Higher lubricant yields are obtained than are available from the mechanical mixture of the olefin polymer and the solvent-raffinate from the mineral oil fraction. It is believed that the polymer reacts not only with the unsaturates in the mineral oil distillate but also with the aromatic compounds in the potential extract phase. The resulting lubricant is said to be of high quality.

Storch, in his excellent recent survey on the Synthine process,[132] quotes various German experimenters to the effect that the large increase in viscosity noted in the oxidation of lubricants produced by Synthine olefin polymerization is "associated with the formation of acidic and saponifiable substances, although the amounts of asphalt or coke formed are extremely small. * * * Thorough hydrogenation of the oil increased the chemical stability."

Koch[317] reports that such synthetic lubricants contain one or two double bonds and about one naphthenic ring per molecule. Kreulen,[319] however, upon hydrogenating two polymer lubricants, determined that some 50 percent of the carbon atoms occur in the branched paraffin chains and that these oils contain either 1.2-1.8 or 2.3-4.0 rings per molecule, depending upon the type of test employed.

The hydrogenation of Synthine-derived lubricants, incidentally, is said to yield lubricants of higher viscosities, although little effect upon viscosity index is reported. Differences in certain of the finished oils are said to depend upon the variation in the olefin concentration and the constitution of the olefin isomers initially present.

Koch[208] is quoted as reporting that the Synthine process yields alpha olefins as the most likely primary products, beta olefins then being formed by isomerization. An increase in the ratio of H_2/CO increases the concentration of beta olefins; "a higher operating pressure gives more alpha olefins; the use of an iron catalyst (at 10 atmospheres pressure) produces a higher concentration of alpha olefins (than does cobalt at normal pressure)."

According to the previously-quoted testimony of Martin,[26] the production of Synthine waxes is more economic by use of the usual cobalt catalyst than through use of the very-high-wax-yielding ruthenium catalysts, although this logic appears based on "the extreme scarcity of ruthenium." Wax, as mentioned, is an important raw material (via cracking or chlorination) for the synthesis of lubricants, and reference to further details may be found elsewhere in this article.

No attempt will be made here to detail the general literature references on the synthesis of lubricants from Synthine products, since these were reported in detail last year,[335] as mentioned. There are a few important primary references,[306, 307] and a number of reviews.[132, 140, 300, 315, 328, 329]

It is by no means certain that the more recent German data have answered all of the questions in regard to the quality of Synthine-based lubricants, since a considerable discrepancy may be noted between certain German claims and tests on captured oils. Nevertheless, it still appears true that satisfactory (even excellent) lubricants can be produced by several different methods from the Synthine primary products produced by normal (paraffin- and olefin-producing) Synthine processes.

By-Products

As mentioned, the Synthine process yields primary products which are fertile source materials for chemical synthesis. In fact, one German (Lurgi) chemist, Dr. H. Otken, has even gone so far as to state[115] that the Synthine process "is extremely important, particularly from the point of view of production of chemicals rather than light fuels."

In general, the methods of chemical synthesis used in converting Synthine products into other substances are much the same as those which have been studied or used in this country for the preparation of "chemicals" from petroleum.[336] The actual products, however, often differ markedly, for the Germans concentrated upon the synthesis of products which were usually of natural origin and were not available in Germany in sufficient quantities. Economics, in many cases, were disregarded, and some of the products were *ersatz* in both the German and American sense. However, many are of present or potential interest in this country.

Fatty Acids

The Germans particularly excelled in the production of fatty acids by the catalytic oxidation of Synthine paraffin wax. Such synthesis has recently been extensively reviewed,[332] and the basic details (applicable, to some extent, to paraffin wax from crude

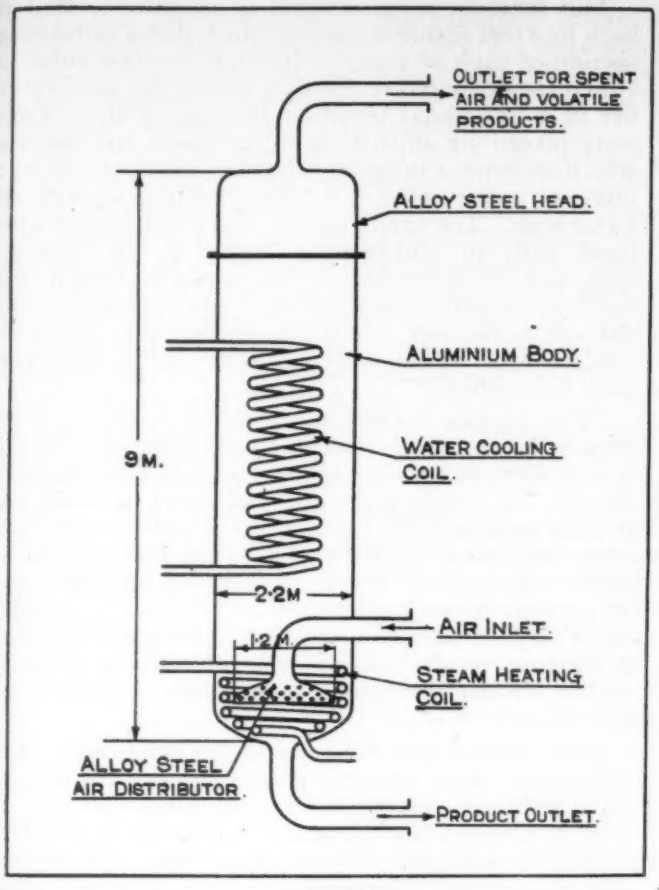


FIGURE 1

Wax oxidation kettle for production of fatty acids (Deutsche Fettsaure Werke, Witten).

oil) have been known for some time. Incidentally, it is interesting to note[14, 132] that small percentages of fatty acids (perhaps 0.35 percent by weight of the main liquid hydrocarbon product) are formed during the normal Synthine process, and "it is by no means impossible that direct synthetic production of fatty acids (perhaps by a Synthol-type variation) will yield high-molecular acids in addition to the mixture of formic, acetic, and propionic already obtained as a by-product of present processes."[14]

Storch reports, in his recent survey,[134] that, while the oxidation of paraffins is strongly exothermic, the process can be controlled to yield chiefly monocarboxylic acids. Operating conditions of 284-320° F. are reported, with the use of 16 cubic feet of air per pound of wax in the presence of such catalysts "as manganese and other metal salts of fatty acids." In his recent general survey, Thompson[140] quotes several authorities to the effect that the C_{20}-C_{35} Synthine fraction (boiling above 662° F.) is most suitable for oxidation, chiefly with manganese salts as catalysts. Both Storch and Thompson mention, in passing, a British patent[339] which describes the oxidation with hydrogen peroxide of Synthine olefins of C_6 and higher, such as a Synthine naphtha containing 50 percent mono-olefins.

Conradi, upon interrogation,[293] has mentioned laboratory work at Oppau in which oxidation tests were carried out at 302° F. and at 15-20 atmospheres pressure, "using a cobalt catalyst which, however, proved troublesome because it gave inconsistent results." Quirk[115] states that "Castrop-Rauxel soft wax was going to the Deutsche Fettsaure for oxidation to fatty acids."

One OPB report[295] describes in detail the operations of the Deutsche Fettsaure plant at Witten in the Ruhr. This plant had a capacity of 40,000 tons per year of fatty acids and was one of three similar works in Germany, the others being of 20,000 tons annual capacity. A fourth plant, designed to operate under 25 atmospheres pressure, was under construction at Magdeburg; Imhauser "claims that this process is six times more expensive than that used in his plant."

The process used at Witten comprises the charging of 8-20 tons of Synthine paraffin wax and 0.2 percent of $KMnO_4$ in 15 percent aqueous solution at 230° F., reacted with 17,665 cubic feet of air per hour per ton of wax for 20-24 hours. The wax charge consists of one part of fresh wax to 1.8 parts of recycle "USM" (unsaponifiable material). Upon completion of the oxidation, a sequence of washing, neutralizing, saponifying, heating, distilling, and acid hydrolysis steps, followed by vacuum distillation, yields the synthetic wax fractions described in Table 11.

The reactor used is shown in Figure 1. Aluminum is the most satisfactory (noncatalytic) material, although alloy steel heads are necessary because "aluminum is corroded by the low-molecular-weight volatile fatty acids."

All of these plants are said to operate under "the same method as that worked out by the Jasco Company of America who hold licenses from I.G. allowing them to use the patents";[296] these patents, incidentally, were among those whose seizure by the Alien Property Custodian has recently been upheld in a decision by Federal Judge Wyzanski.

According to both these reports,[295, 296] the first fraction, the C_1-C_4 acids, "are recovered from the effluent gases by cooling and absorption in water. The formic acid (in Germany) is used mainly for the treatment of fodder silos, the acetic and butyric for the esterification of cellulose, and the propionic (in the form of calcium propionate) as a preservative in bread."

The C_5-C_{10} acids, obtained as the first product from the vacuum distillation, are further distilled into C_5-C_7, C_7-C_9, and C_9-C_{11} fractions. The first two yield higher alcohols upon hydrogenation, these in turn being reacted with phthalic anhydride to yield alkyd resins; the last fraction is normally used for the separation of minerals by flotation. The C_7-C_9 fraction also finds use in fire extinguishers of the foam type.

The C_{10}-C_{18} fraction, also separated by vacuum distillation (at 3 mm. pressure), is used directly in the manufacture of soaps and edible fats (see later sections), although, in the production of the latter, the C_9-C_{16} fraction is usually employed, following removal of dicarboxylic acids by treatment with dilute sodium hydroxide.

The next higher fraction, the C_{18}-C_{24} acids, are also separated by vacuum distillation at 3 mm. These acids have been used in greases, as softening agents for leather (in combination with triethanolamine),

TABLE 11

Various Synthetic Fatty Acid Fractions

	Light Fraction	Main Fraction	Heavy Fraction	Residue
Temp., °F.	<248	248-517	517-597	.....
Yields, percent	15-20	55-60	7-12	7-13
Mol. Wt.	C_8-C_{10}	C_{10}-C_{20}	C_{21}-C_{28}	....
Neut. No.	450-460	245	155-160	80-90
Sap. No.	450-460	255	175-180	110-120
Estn. No.	0-1	10	20	30
Estn. No. for Edible Fats	....	1.5	10	....
U.S.M., percent	....	1.5	10.0	....
U.S.M., percent for Edible Fats	....	Ca. 1	....	....

and (as zinc, magnesium, and calcium soaps) as lubricants for plastic molding. Molding agents for foundry cores, "artificial vaseline," and softeners for plastics (certain alcohols and glycols, produced by hydrogenation) have all been produced from the pitch residue.

Edible Fats

Large quantities of edible fats have been produced in Germany by the saponification with glycerine of selected Synthine fatty acids; at least 90 percent of fats so produced can be assimilated by the body. Incidentally, it is interesting to note that these fats—and other products produced from synthetic fatty acids based upon Synthine paraffin wax—contain acids of both odd and even numbers of carbon atoms, unlike those produced naturally, which always possess even numbers of carbon atoms. About 150 tons of these edible fats were produced monthly at Witten; "appearance and taste are very similar to oleomargarine."[295]

This report[295] contains a flow sheet showing saponification of the C_8-C_{20} acids (3-4 percent in excess) with glycerine in the presence of 0.2 percent metallic tin at 392° F. and 2 mm. pressure. The triglyceride formed is washed with acid to remove the catalyst, neutralized, treated with active charcoal and bleaching earth, filter pressed, steamed at 392° F. under 2 mm. pressure, emulsified with 20 percent water, chilled, milled, and sold for vitamin addition.

Soaps and Synthetic Detergents

Soaps were produced in very large quantities from Synthine fatty acids, but it is admitted[295] that the German producers, even with only 30 percent Synthine soap in the final product, "had not succeeded in removing the characteristic Fischer-Tropsch (Synthine) odor when washing hands. This odor is apparently due to a slight hydrolysis of the soap, and the odor is reminiscent of butyric acid." As mentioned,[296] the C_{10}-C_{18} fatty acids are used in soap manufacture; the latter process apparently does not differ from the standard methods of making soaps from natural fatty acids.

As regards synthetic detergents, large quantities of sulfonic esters were produced from those long-chain alcohols which are prepared from Synthine olefins by the "OXO" process (described in detail later in this article).

"Castrop-Rauxel. heavy (Synthine) oil was going to Leuna for sulfo-chlorination into detergents."[115] Keunecke[296] is "aware of the existence of a soap powder substitute which contained no fatty acids * * * produced to the extent of 60,000 tons per annum by the Leunawerke at Merseburg under the trade name of 'Mersol'." He believed it "to be made from hydrocarbons by treatment with sulfur dioxide and chlorine."

This latter process has been described in detail.[301] Synthine gasoil of 446-624° F. boiling range and an average, straight-chain length of 15 carbon atoms was first catalytically hydrogenated at 571-661° F. and under 200 atmospheres pressure, in the presence of a nickel tungstate catalyst (in order to remove oxygen compounds and unsaturates), then treated with sulfur dioxide and chlorine at 86-104° F. while undergoing irradiation with "ultra-violet" light. The primary product had the type formula $C_nH_{2n+1}SO_2Cl$, while compounds of the formula $C_nH_{2n}(SO_2Cl)_2$ were produced as secondary products.

The reactors were vertical steel towers, 20 feet high by 8 feet inside diameter, "the bottom or reacting section of each of these containing 16 glass tubes of 7-inch inside diameter running across the steel cylinder in a horizontal position. In each of these there were placed six 40-60W daylight lamps (of the type which start on a tungsten filament, then operate as a mercury vapor light). * * * The reacting section was 8 feet high." The entire reactor and all pipe lines were lined with an acid-resistant resin of the "Haveg" type, and the upper part of this vessel was filled with rings of the same composition. The Synthine fraction entered at the top, while the chlorine and sulfur dioxide entered at the bottom. Other equipment details have been given.[301]

"The reaction is carried to only 70 percent of completion, as too much disulfonyl chloride is formed if it is attempted to react more than this percentage of the oil. The product, for the most part, was shipped to soap makers (who saponified it together with their other soap-making materials). * * * The product as made contained 30 percent unreacted oil and about 70 percent of sulfonyl chlorides. Of the 70 percent, 50-60 percent was monosulfonyl, the remainder being a mixture of di- and higher sulfonation products which are useless in the soap which is made from the Mersol."[301]

Quantities of this Mersol (sulfonyl chloride) "soap substitute" were prepared in the form of the sodium alkyl sulfonate (made by saponification at 158° F. with 10 percent NaOH solution) for use in the preparation of polyvinyl chloride emulsions; this sodium salt was termed "Mersolat." A cresol ester of Mersol was also used to plasticize polyvinyl chloride.[301]

It has been reported[323] that the detergent produced by saponifying Mersol "was of very inferior quality. A later product called Mersolat H, made by a somewhat modified process, was considerably better. * * *

"Some of the better known Igepons (high-grade detergents) were derived from oleyl chloride, made from synthetic oleic acid by condensation with the sodium salt of hydroxyethanesulfonic acid or the sodium salt of methyltaurine."

Detergents of the Igepal variety, made by condensing ethylene oxide with fatty alcohols or alkyl phenols, were "suitable for washing cotton and rayon" when containing 10-14 oxyethane groups and "excellent for emulsifying mineral oils" when having 20-30 oxyethane groups. "The introduction of a sulfonic group changed the Igepal from a nonionic to an anionic detergent.

"A great deal of work was done on emulsifiers, the Emulphors being perhaps the most important." One of these was the cyclohexylamine salt of Mepasin ph-sulfonic acid and another the sodium salt of Mepasin sulfamidoacetic acid. These were such excellent cutting oils and drawing compounds that their use was almost entirely restricted to these important war needs. They were quite outstanding for this purpose because they were emulsifiers which had great metal affinity and because they contained a rust-preventing polar group.[323] Other Synthine-derived detergents and emulsifiers were also prepared by the Germans.

Greases

Greases, apparently, were also produced in appreciable quantities from soaps of oxidized paraffins and from either synthetic or natural oils. As mentioned,

the C_{18}-C_{24} fatty acids from the oxidation of Synthine paraffin wax "have found application in greases as sodium, calcium, and lithium soaps. * * * The zinc, magnesium, and calcium soaps have also been used as lubricants for plastic molding. * * *

"In connection with the use of the C_{18}-C_{24} acids in grease manufacture, Dr. Keunecke was asked if he knew anything of developments in Germany on tropical greases, and he stated that they had found that the addition of 2 percent calcium benzoate to a soda-base grease made with synthetic fatty acids would render it water-resistant without lowering the melting point, which was of the order of 392° F. The exact proportion of calcium benzoate was varied a little according to the type of fatty acid concerned."[296] Some miscellaneous information on greases is reported elsewhere.[294]

The "OXO" Process

In addition to those alcohols produced as part of the primary products of the German (and perhaps American) "Synthol" processes, which were described in earlier articles of this series; to those produced by deliberate synthesis over special catalysts under specific conditions, such as methanol and isobutanol; and to those prepared (as mentioned) in the conventional manner by H_2SO_4 hydration of the corresponding olefins, such as amyl and hexyl alcohols, the Germans were preparing at the close of the war to produce 8000 to 10,000 metric tons of alcohols per year in a Ruhrchemie plant by the "OXO" process.[337]

This process involves the treatment with CO and H_2 of such olefins as a Synthine C_{11}-C_{17} fraction at 275-302° F. and 150-200 atmospheres pressure over a cobalt-containing regular Synthine synthesis catalyst, followed by reduction of the resulting aldehydes at 355° F. under 150 atmospheres over either similar catalysts or such cheaper catalysts as those containing nickel.[115, 337] The Synthine olefins could be produced by dehydrogenation of a C_{16}-C_{18} Synthine cut over a catalyst whose preparation has been described.[326] At Holten, the C_{11}-C_{17} cuts were experimentally separated into four narrow cuts and were treated separately. Olefinic fractions from the primary Synthine liquids were also employed, as were olefins from the low-temperature cracking of Synthine wax.[337]

Magnesium was excluded from the catalyst for the first stage "if at all possible." The sulfur-free water gas contained 39 parts of CO to 45 parts of hydrogen. "The process was intermittent, each cycle taking 20 minutes;" temperatures were controlled by means of steam pressure.[326]

Olefins "having from 3 to at least 20 carbon atoms"[337] can be converted into aldehydes by the first step of the process; for example:

$$\underset{\text{PROPYLENE}}{C_3H_6} + CO + H_2 \rightarrow \underset{\text{BUTYRALDEHYDE}}{CH_3CH_2CH_2CHO}$$

It was claimed[326] that adipic acid could be made by oxidation of the hexandial produced from α-butylene or butadiene. In addition to the primary use of the alcohols produced from C_{11}-C_{17} Synthine olefins—the production of sulfonic ester detergents—"plasticizers were also made by applying the OXO process to the C_7-C_{10} olefin mixtures and subsequently forming the phthalic acid ester of the alcohols produced.[337]

A process called the "Synol" process has been mentioned in considerable detail in two references.[312A, 337] This process, similar perhaps to the "Synthol" process, produces alcohols directly from CO and H_2 over a specially-reduced iron catalyst at 364-383° F. under 20-25 atmospheres pressure; in a sense, it "might be looked upon as the OXO process under slightly different conditions applied to nascent olefins *in situ*. * * * Though the *major* yield is of alcohols in the carbon-atom range of C_4-C_8, *some* higher-molecular-weight alcohols are formed."[337]

Returning to the OXO process, the aldehydes produced in the first step can, if desired, be separated and marketed as such, although there is "considerable conversion of aldehydes to alcohol * * * in the first stage," which prevents high aldehyde yields, based on the olefins. In fact, the Germans recommend production of the alcohol by the OXO process, then oxidation back to the aldehyde when the latter is desired.[337] Many further details of the OXO process and its products have been reported.[312A, 337] As originated by Ruhrchemie A.-G., the OXO process was a batch operation. However, the cooperative efforts of Ruhrchemie and I.G. Farbenindustrie resulted in the development of a continuous process, the latest operating details of which have been recently published.[312A]

Miscellaneous Chemicals

In addition to the chemical products already mentioned, numerous other derivatives can be produced from Synthine primary products or from the basic reactants, carbon monoxide and hydrogen.

It is said[14] that formaldehyde synthesis may become possible if sufficiently high pressures and active catalysts can be achieved; "Prof. Fischer himself regards it as not impossible to synthesize even carbohydrates," a hope perhaps "too theoretical to arouse practical interest." Among reactions on Synthine products not previously mentioned in this article, however, are the following selections from a list by Fischer[129]:

"Addition of CO and H_2O to olefins to make acids;
"Addition of CO and H_2O to alcohols to make acids;
"Production of glycols from olefins;
"Isomerization of paraffins; e.g., hexane and neohexane;
"Alkylation, thermal and catalytic;
"Aromatization;
"Conversion of isobutylene to Butyl rubber and high polymers;
"Polyhydric alcohols from olefins and paraffins via chlorination; e.g., glycerol;
"Carboxy-chlorination of paraffins; etc."

Many of those reactions, as mentioned, are identical with those used in the synthesis of chemicals from crude petroleum and its fractions. Others, however, are not in general use.

Isobutanol, for example, was synthesized from H_2 and CO (18-20 percent of the latter) in yields of 10 percent (plus 55 percent yields of methanol and 13.8-15.8 percent of higher alcohols) under pressures of 300 atmospheres in special converters; "methanol was recycled to the reaction." Conradi states that isobutanol was made at Oppau, Leuna, Hydebreck, and Auschwitz "by a variation of the methanol synthesis * * * at a temperature approximately 180° F. higher than that used for methanol synthesis at 200-300 atmospheres pressure, and at a lower space velocity. The standard methanol catalyst is used, but with the addition of alkali."[293]

The isobutanol so produced was dehydrated to yield isobutylene and then converted into isooctane; 40,000 tons of the latter were produced per year by this process at Hydebreck.[313] The higher alcohols

produced at this plant were hydrogenated to yield isoparaffin hydrocarbons which were also used in aviation gasoline blends.

It is worthy of note, incidentally, that the "Hydrocol process"[314A] will produce, as by-products from 64,000,000 cubic feet of natural gas per day, 150,000 pounds *per day* of "crude alcohols in water solution," consisting chiefly of "acetaldehyde, acetone, and ethyl, propyl, butyl, amyl, and heavier alcohols."

At Leuna, alkylbenzenes were produced using C_7 and C_8 alcohols "from the higher alcohol process."[313] The same report states that "glycerine was made at Hydebreck from propylene made by dehydrogenation of the propyl alcohol from higher alcohol synthesis * * * 2000 tons per year was achieved."

"Aldehydes were made at the Leuna plant from the alcohols produced there. Fatty acids were (also) made at this plant from the highest fractions of the alcohols remaining from isobutanol manufacture by caustic fusion and precipitation with sulfuric acid."[301] A castor oil substitute was prepared by esterifying some of these acids with trimethylolethane; the remainder were used for the production of "Solagen" driers in the form of cobalt and manganese salts.

Some of the isobutylene produced at Oppau was used for the production of polyisobutylene, known in Germany as Oppanol and in this country as Vistanex, etc. Ethylene was added to the isobutylene, and the latter was then polymerized on a moving steel belt at —150° F. "by allowing the ethylene to evaporate; it was then recompressed and used again. The catalyst, 1 percent of BF_3, was added at the beginning of the belt."[293] Conradi stated that Oppanol was being used to raise the viscosity index of lubricants and as cable insulation. "It is already known that the addition of 1 percent butadiene prior to polymerization enables the final product to be vulcanized"[293]; this is similar, presumably, to Butyl rubber.

Various other materials can be produced. By-products of Synthine wax oxidation include dicarboxylic acids and various aldehydes, alcohols, and ketones.[321] Sulfonic acids obtained from Synthine hydrocarbons have been used for the preparation of water-soluble cutting oils.[298] Ketones for use in the cosmetics industry or as plasticizers have been produced by the saponification with lime of Synthine fatty acids; the resulting calcium salts are destructively distilled at atmospheric pressure and the crude product redistilled under vacuum. Since most of the ketones produced from a heterogenous mixture of fatty acids boil between 464-571° F. and have melting points between 14° and 86° F., it has been assumed that these ketones contain 12-17 carbon atoms.[291,292,325]

The above ketonization, followed by hydrogenation, is used on the pitch residue of the distillation of Synthine fatty acids to yield long-chain saturated hydrocarbons "which are claimed to be an excellent substitute for vaseline."[296] The heavy cut from the $AlCl_3$ polymerization of Synthine olefins, previously described under synthetic lubricants, has been used in France to produce "a substance similar to vaseline, which is being used by the cosmetic industry" by hydrogenation at 392° F. under 100 atmospheres pressure over standard (cobalt-thoria-magnesia-kieselguhr) Synthine catalysts.[290]

Variations of the Synthine process, described in the second article in this series, are "iso-synthesis" and the synthesis of aromatic hydrocarbons.[26,190,208] These processes make possible the preparation of a wide variety of isoparaffins, aromatics, and naphthenes, and, if economic, will serve "to round out" the Synthine process as a source of chemical materials. Space here does not permit discussion of methanol synthesis from carbon monoxide and hydrogen, but this process is in wide use in this country and is well understood. Reference may also be made to the second article in this series for a discussion on methane synthesis. The production of "synthetic natural gas" from coal is of some interest in this country at present,[314A] and this interest may very well increase.

* * *

The basic economics of the Synthine process and its current status will be the subject of the remaining article of this series.

BIBLIOGRAPHY

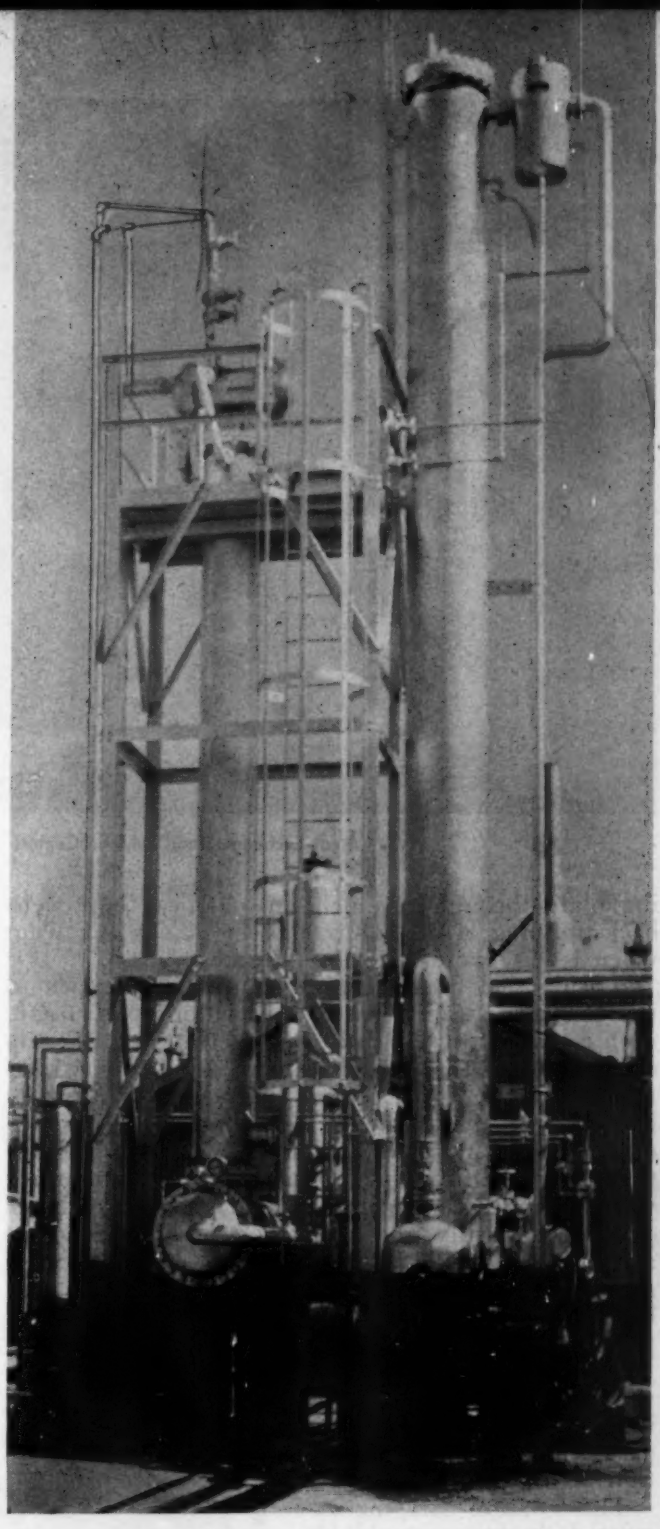
[290] Aldrich, R. C., Office of Publication Board Report No. 365, Department of Commerce, Washington, D. C.; National Petroleum News, Technical Section **37**, No. 45, R-859 (1945).
[291] Anon., Petroleum Times **48**, No. 1234, 747 (1944).
[292] Anon., Chemical and Engineering News **22**, No. 23, 2114 (1944).
[293] Anon., Office of Publication Board Report No. 9, Department of Commerce, Washington, D. C.
[294] Atwell, H. V., and Schroeder, W. C., Office of Publication Board Report No. 283, Department of Commerce, Washington, D. C.
[295] Baldeschwieler, E. L., Office of Publication Board Report No. 225, Department of Commerce, Washington, D. C. (also T. O. M. Report No. 21 and T. A. C. Report SnMC-7).
[296] Bellamy, L. J., and Nillson, K. T., Office of Publication Board Report No. 6, Department of Commerce, Washington, D. C.
[297] Bender, R. J., National Petroleum News, Technical Section **38**, No. 6, R-105 (1946).
[298] Bolzau, W., Oel und Kohle **39**, 416 (1943).
[299] Borisov, P. O., and Eventova, M. S., Neftyanoe Khozyaistvo **1939**, No. 12, 43; Khim. Referat. Zhur. **1940**, No. 6, 110.
[300] Bridgwater, R. M., Petroleum **8**, No. 7, 136; No. 8, 152 (1945).
[301] Calcott, W. S., Office of Publication Board Report No. 187, Department of Commerce, Washington, D. C.
[302] Cotton, E., National Petroleum News, Technical Section **38**, No. 23, R-425 (1946).
[303] Dannefelser, W., Oel und Kohle **38**, 363 (1942).
[304] Davies, V., Industrial Chemist **13**, 442 (1937).
[305] Egloff, G., Nelson, E. S., and Morrell, J. C., Industrial and Engineering Chemistry **29**, 555 (1937).
[306] Fischer, F., and Koch, H., Brennstoff-Chemie **14**, 463 (1933); Petroleum Refiner **23**, No. 7, 106 (1944).
[307] Fischer, F., Koch, H., and Wiedeking, K., Brennstoff-Chemie **15**, 229 (1934); Petroleum Refiner **23**, No. 8, 116 (1944).
[308] Fischer, F., and Weinrotter, F., Brennstoff-Chemie **21**, 209 (1940).
[309] Gross, H., and Grodde, K. H., Oel und Kohle **38**, 419 (1942).
[310] Hall, C. C. and Haensel, V., Technical Oil Mission Report No. 44, July 5, 1945.
[311] Hall, C. C., Technical Oil Mission Report No. 10, August 17, 1945.
[312] Hammerich, T., Oel und Kohle **37**, 148 (1941).
[312A] Holroyd, R., "Report on Investigations by Fuels and Lubricants Teams at the I. G. Farbenindustrie A.-G. Works at Leuna," September 24, 1945. Obtainable from U. S. Bureau of Mines.
[313] Holroyd, R., Office of Publication Board Report No. 38, Department of Commerce, Washington, D. C.
[313A] Horne, W. A., and Faragher, W. F., U. S. Technical Oil Mission Microfilm Reel 199, FIAT Report 426, "Interrogation of Dr. Pier and Staff, I. G. Farbennidustrie, A.-G., Ludwigschafen-Oppau."
[314] Horne, W. A., and Jones, J. P., Office of Publication Board Report No. 294, Department of Commerce, Washington, D. C.
[314A] Keith, P. C., Oil and Gas Journal **45**, No. 6, 102 (1946).
[315] Kelly, C. I., Petroleum Times **50**, 369 (April 13, 1946).
[316] Koch, H., and Ibing, G., Brennstoff-Chemie **16**, 141 (1935); Petroleum Refiner **22**, No. 9, 89 (1943).
[317] Koch, H., Brennstoff-Chemie **19**, 337 (1938).
[318] Kolbel, H., Brennstoff-Chemie **30**, 352 (1939).
[319] Kreulen, D. J. W., Chem. Weekblad **36**, 410 (1938).
[320] Landen, E. W., SAE Journal **54**, No. 6, 270 (1946).
[321] Manner, L., Die Chemie **57**, 6 (1944).
[322] Martin, F., Industrial Chemist **13**, 320 (1937).
[323] Murray, R. L., Chemical Industries **58**, No. 5, 738 (1946).
[324] Oberfell, G. G., National Petroleum News, Technical Section **38**, No. 1, R-46 (1946).
[325] Ohme, W., Oel und Kohle **40**, 87 (1944).
[326] Oriel, J. A., CIOS Report, TIIC Index No. 3; National Petroleum News, Technical Section **37**, No. 45, R-926 (1945).
[327] Pichler, H., and Buffleb, H., Brennstoff-Chemie **21**, 285 (1940).
[328] Pickston, P. W., Petroleum **7**, No. 7, 124 (1944).
[329] Piganoil, M., Petroleum Refiner **24**, No. 5, 111 (1945).
[330] Sergienko, S. R., Investiza Akademii Nauk U.S.S.R. Otdelenie Khim Nauk **1941**, 191.
[331] Snodgrass, C. S., and Perrin, M., Journal of the Institution of Petroleum Technologists **24**, 289 (1938).
[332] Stossel, E.. Oil and Gas Journal **44**, No. 11, 130; No. 15, 145, No. 17, 69 (1945).
[333] Teet, H. C., and Dees, H. C., Office of Publication Board Report No. 101, Department of Commerce, Washington, D. C.
[334] Velde, H., Oel und Kohle **37**, 143 (1941).
[335] Weil, B. H., National Petroleum News, Technical Section **37**, No. 27, R-512 (1945).
[336] Weil, B. H., Chemical and Metallurgical Engineering **52**, No. 12, 121 (1945).
[337] Weir, H. M., Technical Advisory Committee Report A1ML-1, July 30, 1945.
[338] Brit. 449,274 (1936), to I. G. Farbenindustrie A.-G.
[339] Brit. 492,595 (1938), to Deutsche Hydrierwerke A.-G.
[340] Brit. 517,002 (1940), to Studien-und Verwertungs G.m.b.H.
[341] French 824,893 (1938), to Studien-und Verwertungs G.m.b.H.

Hydrogen Sulfide Removed From Cracking-Plant Gases

FLETCHER Oil Company's Dubbs cracking plant at Wilmington, California, produces approximately 450,000 cubic feet daily of vapors rich in heavy olefinic gases. Throughout the war emergency these gases were diverted, along with iso- and normal butanes to the manufacture of 100-octane gasoline. Previously these cracking-plant gases were processed in a catalytic polymerization unit, and lately this operation has been resumed so that automotive gasoline manufacture might be improved. Due to the composition of the charging stock fed to the Dubbs plant, sulphur compounds are generated to the extent that H_2S is present up to 2500 grains per 100 cubic feet.

To remove the hydrogen sulphide the company recently built a purification plant. This unit is reducing the H_2S from a mean average of 2500 grains per 100 cubic feet, to 15 grains per 100 cubic feet of gas processed. Discounting the amortization of the construction cost of the extraction unit, the actual expense involved is represented by the utilities required. Steam in the amount of 400 pounds per hour is necessary to operate the solution-circulating pumps and to control the temperature in the process of regenerating the hydrogen sulphide-extracting solution. An ample supply of cooling water is available in the refinery to handle temperatures in excess of any normal operating conditions, so the cost of furnishing and circulating the small quantity of water necessary for the H_2S removal plant is practically nil. Labor costs are not sufficient to be considered as an important item in the operation of the plant as the operators on the regular tour care for the unit, which is entirely automatic. Loss of the active agent, diethanolamine, amounts to approximately 1 pound in 24 hours.

The purification unit was built by the construction department of Fletcher Oil Company. The principal parts of the unit are the absorber in which the cracking plant gases are contacted with the amine solution; the reactivator with which the spent amine is regenerated, and which is comparable to an absorption oil still; reboiler; pumps; heat exchangers, and solution coolers. Operation is piloted by automatic controllers and instruments, both indicating and recording, to control flow, pressures and temperatures as in a gasoline plant. The unit is situated in a direct line with the remainder of the refinery units, and is



Unit for removing hydrogen sulfide from refinery gases at Fletcher Oil Company's Wilmington, California, refinery.

constructed and piped to form an integral part of the catalytic polymerization unit.

In the flow line the vapors are conducted through a manifold from the pressure distillate separator drum to the purification unit at a pressure of 175 psig. The vapors first enter a knock-out drum, 20 inches OD by 4 feet high to trap out any fractions of the vapors which may condense in the transfer line. The knock-out drum is equipped with steam heating coils to maintain an average temperature on the vapors of 125 to 130° F. so that the charge will flow through to the absorber as a gas. The absorber is a vertical column 20 inches OD by 30 feet high, having a plate near the bottom to support a 20-foot column of ¾-inch porcelain Raschig rings. Vapors enter the absorption column below the ring-support-

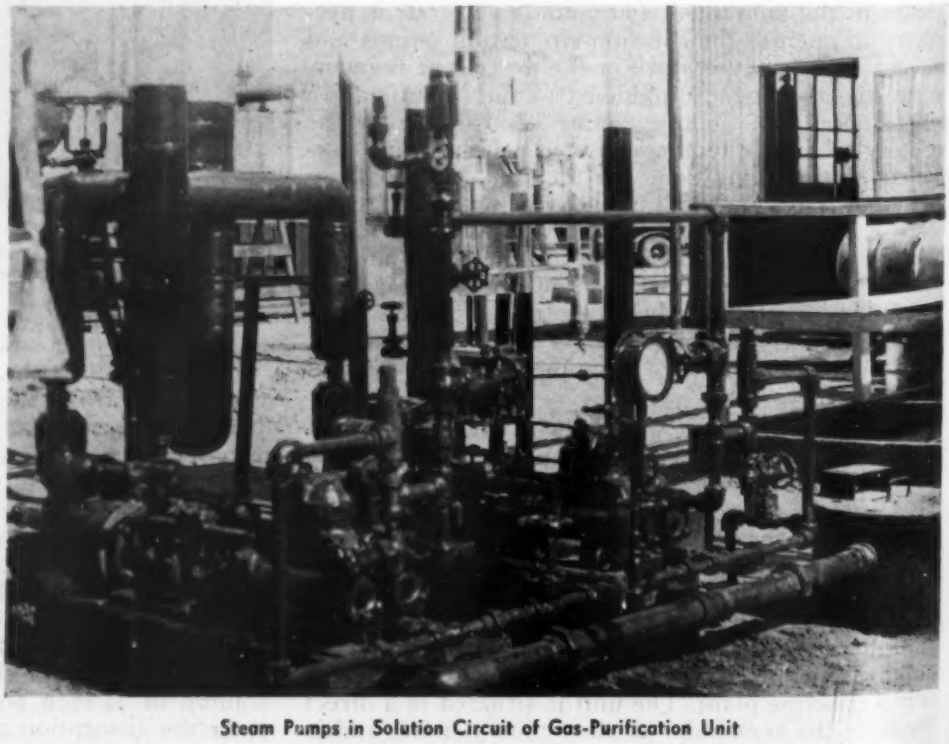
Heat Exchangers and Solution Coolers

ing plate through a 3-inch line, looped to prevent back-trapping of the solution to the knock-out drum when levels fluctuate within the absorber.

Freshly regenerated amine solution is pumped to the absorber at a rate of 3 to 4 gallons per minute with a temperature of 130° F., entering near the top of the column through a ¾-inch line. The gas rises through the bed of porcelain rings, making intimate contact with the extracting solution for the removal of the hydrogen sulphide. The gas leaves the top of the absorber through a 3-inch line to a separator which recovers any solution which may be carried over mechanically, and back-traps the liquid into the absorber automatically. Gas which leaves the absorber contains 15 grains of hydrogen sulphide, as compared to the 2500 grains at the gas inlet, and flows approximately 175 psig, to the intake of the charge compressor of the polymerization plant.

The solution carrying extracted hydrogen sulphide is released from the base of the absorber by a liquid-level controller, equipped with a stainless steel float, to the piping leading to the reactivator. A three-unit heat exchanger receives the solution in counter flow to the reactivated solution leaving the reactivator, to heat the rich and to cool the lean solution. At absorber pressure when the solution leaves the column, it is reduced to a pressure essentially that of the atmosphere as it enters the top of the reactivator. This vessel is 14 inches OD by 17 feet high, containing 15 feet of ¾-inch Raschig rings over which the rich solution falls in contact with the hot vapors and steam rising from the reboiler. The reactivator sets directly upon the reboiler, which is equipped with internal coils for maintaining a temperature of approximately 225° F., at which temperature and operating pressure the solution is boiling. Water vapor and the released hydrogen sulphide passes from the column at the top to flow through a tubular condenser where the water is condensed at 115° F., leaving the free hydrogen sulphide to pass on through a flame arrestor to disposal. Water at a rate of approximately 10 gallons per minute flows through the overhead condenser, and this condensate is back-trapped into the column so as to maintain the required dilution of the amine solution.

Solution in the reboiler is maintained at approximately 225° F., depending upon other operating conditions, flows into a reboiler surge space fitted with a gauge glass to indicate levels, and flows thence through the heat exchanger to a two-section cooler from which the charge pump takes suction, completing the cycle. Steam for heating the solution in the reboiler is supplied by exhaust from the circulating pumps with necessary makeup taken from the refinery steam system, controlled by a flow recording controller so that the predetermined temperature may be maintained on the solution in the reboiler and reactivator column.



Steam Pumps in Solution Circuit of Gas-Purification Unit

Basic Petroleum Chemistry For Refinery Employes

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Chapter VII
PETROLEUM IMPURITIES AND TREATING METHODS

SALT in the crude oil coming from producing wells to the refinery is today one of the most serious problems of the refiner. The principal effects of salt in crude are:

Corrosion of refinery equipment.
Deposition of coke in heater tubes.
Deposition of scale in fractionating and condensing equipment.
Sedimentation in residual oils.

The treating of crude oil should logically begin in the producing field before emulsions have a chance to become stabilized by agitation in pumps and pipe lines.[1] Crude oil is found associated with a solution of water containing salts of aluminum, iron, sodium, calcium and magnesium, with the chloride salt of sodium usually predominating. To a lesser extent crystalline salts may be present, with the solid salt crystals being protected against solution into the water phase by a film of oil or amorphous wax. The chloride of calcium and magnesium are particularly harmful because under the conditions of primary distillation they hydrolize, forming hydrochloric acid which causes severe corrosion of refinery equipment. Effective removal in the field would save refiners millions of dollars annually. Usually no more is done in the field than to draw off accumulated water in storage tanks prior to delivery into pipe lines. A number of factors must be considered in deciding whether the crude will be treated in the field or at the refinery. These factors include such as the company organization, relation of the producer to the refiner, availability of power and other materials required for desalting operations, and the demand or specifications of the crude oil purchaser.

Prolonged contact of the oil and water phase, rapid removal of oil from the wells, and agitation from pumping equipment, contribute to the formation of colloidal emulsions which resist separation.

The acidizing of wells to make limestone formation more porous for increased oil recovery has considerably aggravated the refiner's problem. Some of the acid is carried with the crude to the refinery. More acid is formed by the hydrolysis of calcium and magnesium chlorides. This acid attacks iron forming ferrous chloride. The ferrous chloride is acted upon by hydrogen sulfide, present to some extent in most crude oil, to form iron sulfide and more hydrochloric acid free to attack more metal.

The vicious cycle is represented by the following equations:

$$2\,HCL + Fe \rightarrow FeCl_2 + H_2$$
$$FeCl_2 + H_2S \rightarrow FeS + 2\,HCL$$

An understanding of the refinery problem depends upon accurate and frequent analysis of the crude, being processed. Analytical data carefully compiled usually will reveal the nature and source of the troublesome salts. Such data also is essential in helping to establish the most feasible desalting methods to employ.[2,3,4]

Effective desalting processes now in use depend upon the dissolving of crystalline salts and the resolving of salt-water emulsions with additional water. A variety of methods are then used to separate the oil from the water.

Simple washing of the oil with water at atmospheric temperature and pressure, followed by gravitational settling is satisfactory to a limited degree, provided the oil is relatively low in viscosity and does not contain emulsion-stabilizing substances.

The water and oil are mixed intimately by pumping through orifices or mixing spools into a large tank preferably provided with a conical or sloping bottom. The amount of water used varies between wide limits. A high ratio of water to oil is most effective, but the settling time is prolonged. The more the wash water becomes saturated with dissolved salt, the greater the density of the water becomes, and the more rapid is the settling. The optimum ratio of water to oil can only be established by experimental procedure. Application of heat and pressure to the simple water wash is beneficial, for it decreases the viscosity of the oil and increases the difference of specific gravity between the oil and salt water. It also decreases the surface energy of the enveloping film of each droplet of salt water, causing the film to burst and the water to coalesce. Less water is required in water-wash methods when heat and pressure are applied. The heat for such processes usually is obtained by means of exchange with the residuum from the topping or cracking units.[5,6]

Desalting With Chemicals

Use of chemicals in desalting processes has been covered by numerous patents, most of which first forms an emulsion of oil and water and then add certain chemicals to effect a separation. The chemicals which have been successfully used may be classified into 6 groups.[7] Group 1 consists of chemicals which have a strong tendency to take up water, such as calcium chloride, quick lime, and Portland cement.

Group 2 consists of chemicals which cause flocculation by combining with the emulsifying agents contained in the protective film. The group includes ferrous sulphates, sodium chloride and sodium sulphate.

Group 3 includes chemicals such as sodium hydroxide, sodium bicarbonate, calcium oxide, and so-

dium carbonate, which react with salts or organic acids present in the oil.

Group 4 consists of chemicals which break the enveloping film, such as iron oxide, fine silica, clay, sodium soaps, resin and resin soaps, albuminous materials, gums, starch and organic acid sulphonates.

Group 5 consists of electrolytes that tend to neutralize the electrical charge on the surface of emulsified water. Sulfuric acid, acetic acid, ferric chloride and ferric sulphate are of this group.

Group 6 consists of chemicals which act as solvents and dissolve the material causing the protective films. In the group are such materials as gasoline, carbon disulfide, acetone, benzene, ether, alcohol and carbon tetra chloride.[1,3]

Solid Contact Processes

There are very few commercial processes which today use the solid contact method. The solids may include one or more of the following: fullers earth, clay, sand, excelsior, aluminum oxide, cloth, magnesium silicate and others. They are either mixed with the oil and then separated from it by means of filter presses or placed in a filter bed through which the oil is passed by gravity or pump pressure.

Centrifugal Processes

Small-scale experimental processes have been investigated using centrifuges which have speeds of 15,000 revolutions per minute. These experimental methods have succeeded in reducing the salt in certain oils as much as 99.7 percent. Although one company has conducted investigations for the past nine years on the desalting of raw crude and topped crude by means of centrifugal processes there are few, if any, commercial applications today of centrifugal desalting.

Electrolytic Process

One desalting process in use today is the electrical process, a simplified flow diagram of which is illustrated by Figure 14. The oil is heated to 190° to 210° F. and then mixed with water at approximately the same temperature. The mixture then passes into a vessel where it is subjected to an electrical field. The

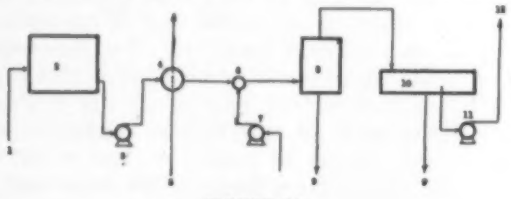


FIGURE 14

Electrolytic Desalting Process

1 Untreated Crude Oil; 2 Crude-Oil Storage; 3 Desalter Charge Pump; 4 Crude-Oil Heater; 5 Hot Oil; 6 Oil-Water Mixer; 7 Water Pump; 8 Electric Treater; 9 Salt Water; 10 Surge Tank; 11 Desalted-Oil Pump; 12 Desalted Crude Oil.

high-potential electrical alternating field charges the minute water particles in the emulsion, causing the enveloping film to rupture and the water particles to coalesce, forming large droplets which readily drop out by gravity. The settled water is withdrawn continuously at a rate sufficient to maintain a constant level of water in the vessels. The process operates at a maximum pressure of about 35 psi. The commercial plants are designed for a working pressure of 40 psi, but usually operate at a considerably lower pressure. They may be designed for either direct or alternating current. The latter is most widely used, and the potential difference ranges from 16,000 to 33,000 volts.[8,9]

Fibrous Glass Desalting Process

One of the most recently developed methods for removing salt from crude was recently announced by the Owens-Corning Fiberglass Corporation. It is claimed that the salt content of crude may be reduced to less than 5 pounds per 1000 barrels at an operating cost of 0.3 cents per barrel, and an investment cost of $3.70 per barrel, for a 10,000-barrel-per-day-unit. The estimates were based upon experimental and pilot-plant investigations. The method involves the mixing of oil and water in a ratio established on the basis of the salt content of the oil. Caustic is added to the mix in sufficient quantity to maintain pH value between 7 and 8. Higher values result in deterioration of the fibrous glass. Lower values result in the corrosion of equipment. The mixture of oil, water and caustic is heated to 250-350° F., and pumped at sufficient pressure to prevent the oil from vaporizing excessively, through a contactor containing multiple beds of .00028-inch diameter glass fibers. Each bed is two to four inches thick. Pressure drop through a single bed exceeding 40 psi results in crushing the bed and immediate loss of efficiency. The preferential wetting of the fibrous glass by the salt brine in the mixtures causes the separation of the brine and crude oil in a settler. No commerial installations are as yet in operation.[10]

Impurities In Refinery and Natural Gas

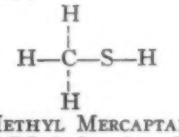
Hydrogen sulfide is the most prevalent impurity found in natural and refinery gas. It is removed because of its corrosive action on iron and steel, and because of its being poisonous and foul smelling.

The molecule of hydrogen sulfide (H_2S) is represented structurally as follows:

H—S—H

HYDROGEN SULFIDE

Sulfur combines with hydrocarbons to form molecules called mercaptans. Molecules of methyl mercaptan (CH_3SH) are also present in some gases. The structural formula is:



METHYL MERCAPTAN

Carbon dioxide (CO_2) is also found in many natural gases. It is represented structurally thus:

O—C—O

CARBON DIOXIDE

Caustic Soda For Treating Gas

Treating processes for natural and refinery gas are designed primarily to remove hydrogen sulfide (H_2S). Caustic soda has long been used for this purpose. It it effective from 0.1 to 10 percent caustic in aquous solution.

The caustic solution usually is contained in a vertical vessel equipped with baffles or filled partially with an inert packing such as porcelain raschig rings, limestone are egg-size brick. The gas enters the bottom of the vessel and bubbles up through the solution, leaving through an outlet in the top of the vessel. Two or more such vessels may be used in series.

As long as available caustic is present in the solution the reactions are:

$$2NaOH + H_2S \rightarrow Na_2S + 2H_2O$$
$$Na_2S + H_2S \rightarrow 2NaSH$$

When the caustic becomes spent partial regeneration may be accomplished by stripping with steam. The reaction may be represented as follows:

$$NaSH + Steam \rightarrow NaOH + H_2S$$

The spent caustic is charged into the upper section

of a packed fractionating column. The solution is stripped by counter-current steam introduced in the bottom of the column. Either an internal or external reboiler may be used to increase the temperature of the caustic in the bottom of the column to approximately its boiling point.[10] The H_2S out of the top of the column may be wasted to the atmosphere or recovered for use in the manufacture of sulfuric acid.

The sodium sulfide (Na_2S) may be recovered by a process which consists essentially of aeration causing hydrolysis of the sulfide, liberation of hydrogen sulfide and recovery of caustic soda. The reactions may be represented as follows:

$$Na_2S + H_2O \rightarrow NaOH + NaSH$$
$$NaSH + H_2O \rightarrow NaOH + H_2S$$

Lime water may be used in a similar manner to wash the hydrogen sulfide from gas, but the volume required is much in excess of the volume required when caustic soda is used.

If the mercaptans in gasoline fractions are of low molecular weight; eg. methyl, ethyl and propyl mercaptans, caustic soda or lime water washes are sometimes sufficient treatment to yield a sweet marketable product. Such washes are advisable for hydrogen sulfide removal prior to treatment with other chemicals.[11]

Phosphate Process

Tripotassium phosphate (K_3PO_4) is the chemical used in a gas treating process developed by the Shell

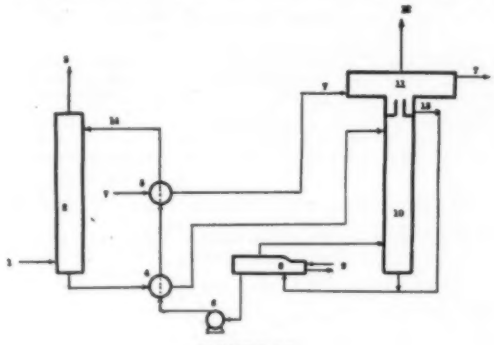


FIGURE 15

Shell Phosphate Process

1 Sour Gas; 2 Packed Absorber; 3 Sweet Gas; 4 Solution Exchange; 5 Solution Cooler; 6 Solution Pump; 7 Cooling Water; 8 Solution Reboiler; 9 Steam; 10 Solution Regenerator; 11 Condenser; 12 Hydrogen Sulfide; 13 Condensate; 14 Regenerated Solution.

Development Company. The reaction is represented as follows:

$$K_3PO_4 + H_2S \rightleftarrows K_2HPO_4 + KHS$$

The gas is contacted with an aqueous solution of the tripotassium phosphate in a conventional bubble plate or packed absorber. The solution is made up by mixing phosphoric acid and potassium hydroxide with water in the ratio of 3 molecular weights of potassium hydroxide (KOH) to 1 molecular weight of phosphoric acid, or 56 pounds of KOH and 98 pounds of H_3PO_4.[12]

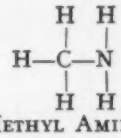
The process may be used for the removal of H_2S from either gas or gasoline.

Since, as indicated in the above equation, the reaction is a reversible one, regeneration of the solution is a simple matter, and is accomplished by merely increasing the temperature of the H_2S-saturated phosphate solution to its boiling point, which is approximately 235° F. The distillate in the solution regenerator contains steam and H_2S. The steam is condensed and the H_2S is wasted to the atmosphere or recovered for use in the manufacture of sulfuric acid.

A simplified flow of a Phosphate Gas-Purification System is illustrated in Figure 15.

The Girbotol Process

The Girbotol Process makes use of organic amines which are compounds containing carbon, hydrogen and nitrogen in their structures. The structure of a simple compound of this group is that of methyl amine (CH_3NH_2).



METHYL AMINE

Hydrogen sulfide and carbon dioxide are removed by the Girbotol Process. The reactions are reversible and may be represented by the equations:

$$2RNH_2 + H_2S \rightleftarrows (RNH_2)_2 \cdot H_2S$$
$$2RNH_2 + CO_2 + H_2O \rightleftarrows (RNH_2)_2 \cdot H_2CO_3$$

where R represents a hydrocarbon radical.

The hydrogen sulfide and carbon dioxide are absorbed in conventional equipment at atmospheric temperature and are expelled in another vessel by increasing the temperature of the amine solution.

The commercial amines which are available and which may be used in the process are: Triethanolamine, Monoethanolamine, Dapol, and Methicol.

The amine solution saturated with CO_2 and H_2S

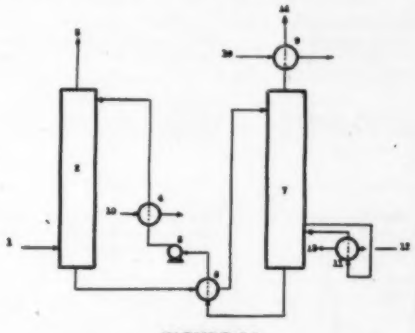


FIGURE 16

Girtobol Gas-Purification System

1 Sour Gas; 2 Absorber; 3 Purified Gas; 4 Solution Cooler; 5 Solution Pump; 6 Solution Heat Exchanger; 7 Reactivator; 9 Condenser; 10 Cooling Water; 11 Reboiler; 12 Exhaust Steam; 13 Steam Condensate; 14 H_2S and CO_2 Gas.

is recovered by stripping it in a bubble tower reactivator where it is raised to 215 to 220° F. temperature by means of a tubular reboiler and open steam.

The process is licensed under patents owned by The Girdler Corporation.[13] Figure 16 represents a simplified flow.

Treating Of Gasoline Distillates

Gasoline distillates are treated for the purpose of improving odor and color, their gum and color stability, octane and lead susceptibility, and to lessen their tendency to corrode metal parts.

The doctor sweetening process is one of the oldest gasoline-treating methods and still is widely used in batch and continuous systems for the sweetening of kerosine. It is losing favor as a gasoline-treating method because it does not effect an appreciable reduction in total sulfur, and by converting mercaptans to disulfides, it reduces the lead susceptibility of the treated gasoline.

Most refineries are changing their gasoline-treating equipment to more modern processes developed in recent years. A convenient summary of the chemistry involved in the more common treating methods in use is found in Table 9 borrowed from an article by Happel, Chauley and Kelly of the Technical Service

TABLE 9
Classification of Gasoline Treating Processes

PROCESS	Chemicals Used	Sweetening Reaction	Complete Sweetening Effect	Regeneration of Treating Solution—Chemical Reaction	Can It Be Controlled to a Mercaptan-Sulfur Specification?	Life of Treating Reagent	Operating Temperature and Pressures	REMARKS
TYPE (1) Doctor	NaOH, PbO, S	$2RSH+Na_2PbO_2+S=PbS+RSSR+2NaOH$[1]	Yes	Air blowing at 160 to 190° F	No	2 to 6 months	Temperature 65 to 100° F. Pressure, atmospheric.	
Lead sulfide	PbS,NaOH	Many variations	Yes	.....	No	.....	Temperature and pressure are both at atmospheric conditions.	
Hypochlorite	NaOCl or Ca $(OCl)_2$	$2RSH+NaOCl=RSSR+H_2O+NaCl$ RSH converted to water-soluble sulfones and sulfoxides.	Yes	Not regenerated	No	.....	Temperature and pressure are both at atmospheric conditions	Finds main use in treating natural gasoline.
Copper processes: Liquid	$CuCl_2$	$2CuCl_2+2RSH=2CuCl+RSSR+2HCl$	Yes	CuCl solution is blown with air at atmospheric temperature. $2CuCl+2HCl+\frac{1}{2}O_2=2CuCl_2+H_2O$	No	.....	Temperature and pressure are both at atmospheric conditions	
Bed	$CuCl_2$	Same as above	Yes	Regenerated in place with atmospheric or pure oxygen Same equation as above	No	.....	Temperature and pressure are both at atmospheric conditions	
Slurry	$CuCl_2$, clay	$2CuCl_2+2RSH=2CuCl+RSSR+2HCl$	Yes	Regenerated in place with pure oxygen Same equation as above.	No	1 to 2 months [5]	Temperature and pressure are both at atmospheric conditions	
TYPE (2) Caustic scrubbing	NaOH	RSH dissolved in treating solution	Depends upon stock	Steam stripping of treating solution	Yes	.....	Temperature and pressure are both at atmospheric conditions	
Shell Solutizer	KOH, isobutyric acid	RSH dissolved in treating solution	Yes	Steam stripping of treating solution	Yes	3 years	Temperature and pressure are both at atmospheric conditions	
Unisol	NAOH, methanol	RSH dissolved in treating solution	Borderline	Distilling methanol and mercaptans from caustic, and separating alcohol and mercaptans	No	Based on loss of 0.004 percent methanol in gasoline	Temperature and pressure are both at atmospheric conditions	
TYPE (3) Sulfuric acid	H_2SO_4	RSH converted to disulfides which are soluble in the sulfuric acid	Depende upon stock	.....	No	.....	Temperature, atmospheric or colder, Pressure, atmospheric	
Gray catalytic desulfurization	Clay	Sulfur compounds converted to H_2S, which is removed by caustic washing or stabilization	Depends upon stock	Not Not necessary	No	About 5,000 bbl. gasoline per ton of clay	Temperature, about 700° F. Pressure, moderate	
Houdry catalytic treating	Special catalytic	Sulfur compounds removed as H_2S in regenerating catalyst	Depends upon stock	Air blowing at 700° F	No	.....	Temperature, 645° F.	
Perco	Bauxite	Sulfur compounds converted to H_2S, which is removed from gasoline	Depends upon stock	Burning in atmosphere of controlled oxygen content	No	2,500 bbl. to 5,000 bbl. of gasoline per ton of catalyst without regeneration	Temperature, 700 to 750° F. Pressure, 20 to 30 psi	

Division of Socony-Vacuum Oil Company.[14] They group the treating processes in common use into three classifications as indicated in the table; Type 1, those which chemically convert mercaptans to disulfides; Type 2, those which remove mercaptans but which do not materially remove other sulfur compounds; and, Type 3, those which remove some or all of the different types of sulfur compounds.

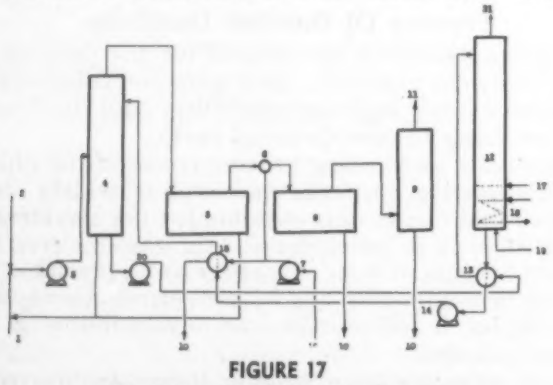


FIGURE 17
Continuous Doctor-Treating Process

1 Untreated Gasoline; 2 Sulfur Solution; 3 Gasoline-Charge Pump; 4 Doctor Reactor; 5 Doctor Settler; 6 Water Mixer; 7 Water-Wash Pump; 8 Water Settler; 9 Gasoline Dehydrator; 10 To Sewer; 11 Treated Gasoline; 12 Doctor-Recovery Tower; 13 Heat Exchanger; 14 Regenerated-Doctor Pump; 15 Doctor-Solution Cooler; 16 Water; 17 Open Steam; 18 Steam Reboiler; 19 Air; 20 Spent-Doctor-Solution Pump; 21 Vent.

In group 1 are the processes which make the odor of gasoline less objectionable by converting the foul-smelling mercaptans to sweet-smelling disulfides. The more common of these processes includes doctor treating, copper-oxide, copper-chloride, hypochlorite, and lead sulfide processes. A simplified flow of a doctor-treating process is illustrated in Figure 17. The reactions are shown in Table 9.

In Group 2 are the caustic scrubbing processes, Pure Oil Company's Mercapsol Process,[15] Universal Oil Product Company's Unisol Process,[16] Shell Development Company's Solutizer Process and Shell and Socony-Vacuum Tannin Solutionizer Process.[17]

Caustic Washing

In caustic washing of gasoline low temperature favors the reaction of the chemical with the mercap-

tan compounds. Caustic strength usually is 8 to 12 percent in aqueous solution. The spent solution saturated with mercaptans is regenerated in a bubble or packed column, with the spent solution entering the top and steam entering the bottom.[18] Equipment for contacting the caustic soda with the gasoline may be similar to that illustrated in the doctor-treating process. Figure 17.

Mercapsol Process

Sour gasoline is first washed with dilute caustic soda in the Mercapsol Process to remove hydrogen sulfide. It is then water washed, sent through a settler and introduced into the bottom of a treating tower where it rises through packing counter-current

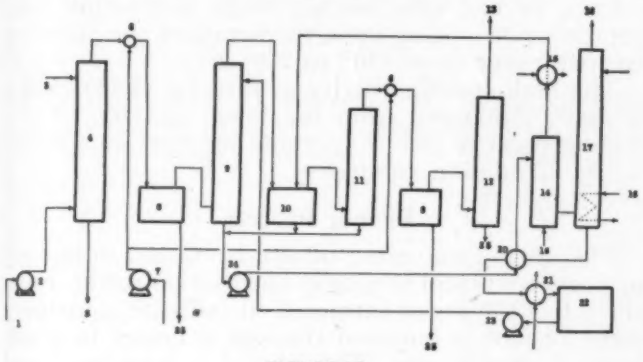


FIGURE 18

Mercapsol Process

1 Untreated Gasoline; 2 Gasoline-Charge Pump; 3 Dilute Caustic; 4 Caustic-Wash Tower; 5 To Waste or Caustic Recovery; 6 Mixer; 7 Water-Wash Pump; 8 Water Settlers; 9 Mercapsol-Contact Tower; 10 Mercapsol Settler; 11 Coalescer Tower; 12 Dehydrating Tower; 13 Treated Gasoline; 14 Gasoline Stripper; 15 Gasoline Condenser; 16 Steam; 17 Mercapsol Regenerator; 18 Vent; 19 Make-Up Water; 20 Heat Exchanger; 21 Cooler; 22 Regenerated Mercapsol; 23 Regenerated-Mercapsol Pump; 24 Spent-Mercapsol Pump; 25 To Sewer.

to the Mercapsol solution. The gasoline then passes through another settling drum and a coalescer tower to remove the last traces of mercapsol. It is then water washed, salt dried and sent to finished storage. A simplified flow diagram is illustrated in Figure 18.

Unisol Process

A simplified flow diagram of the Unisol Process is shown in Figure 19.

Mercaptans are removed from sour gasoline with an aqueous solution of caustic soda, and methyl alcohol. The caustic is continuously regenerated, and the alcohol almost entirely recovered by stripping from the spent caustic solution.

Tannin Solutizer Process

Sour gasoline is first pre-washed with caustic soda solution to remove hydrogen sulfide. It is then contacted in packed column counter current to the solutizer solutions containing alkyl phenols and/or isobutyric acid. The spent solution is heated to 90° - 135° F. with exhaust steam and is then passed through a packed vessel in order to recover entrained gasoline. The solutizer solution then goes to a regenerator where mercaptans are converted to disulfide, the disulfides are separated, the solutizer solution cooled and returned to the packed column. Figure 20 is a simplified flow diagram.

Catalytic Desulfurization

The catalytic gasoline treating processes include those which remove several types of sulfur compounds by passing the vaporized gasoline through a catalytic chamber at elevated temperature, usually followed by fractionation to remove the polymers. In this group are the Gray, Perco, and Houdry catalytic desulfurization processes.

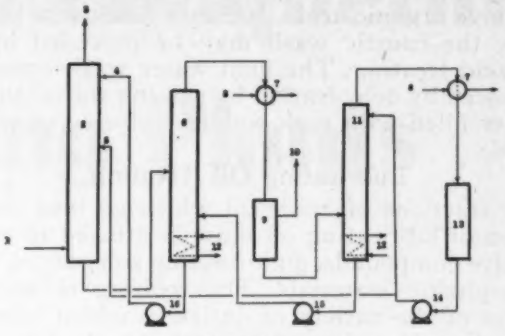


FIGURE 19

Unisol Caustic-Methanol Process

1 Sour Gasoline; 2 Packed Column; 3 Treated Gasoline; 4 Caustic Soda Solution; 5 Methanol; 6 Stripping Column; 7 Condensers; 8 Cooling Water; 9 Mercaptan Separator; 10 Mercaptans; 11 Methanol Fractionator; 12 Steam Reboilers; 13 Methanol Accumulator; 14 Methanol Pump; 15 Recycle Pump; 16 Caustic Pump.

Treating For Octane Improvement

The processes which merely convert mercaptans to disulfides have a degrading effect on octane value. Furthermore the presence of disulfides in gasoline counteract the effect of tetraethyl lead.

Those processes which actually remove mercaptans and those which remove mercaptans and other sulfur compounds, improve the octane value and lead susceptibility of most gasolines.

It has been found that by causing tetracarbonyls

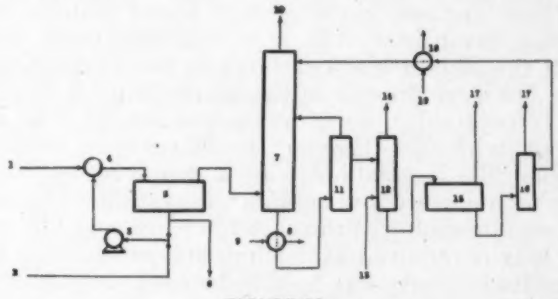


FIGURE 20

Tannin Solutizer Process

1 Sour Gasoline; 2 Make-Up Caustic; 3 Caustic Pump; 4 Mixer; 5 Caustic Settler; 6 Spent Caustic; 7 Packer Column; 8 Heat Exchanger; 9 Steam; 10 Treated Gasoline; 11 Gasoline Coalescer; 12 Regenerator; 13 Air; 14 Exhaust Air; 15 Disulfide Separator; 16 Disulfide Coalescer; 17 Disulfide Oil; 18 Cooler; 19 Water.

of iron and cobalt to react with the mercaptans in gasoline, tricarbonyl mercaptides are formed which not only sweetens the gasoline but also increases its octane value. Table 10 shows the results of experimental treating.

Thus the more mercaptans contained in the gasoline the higher the octane value when treated with sufficient carbonyl to convert all of the mercaptans to carbonyl mercaptides.

Light Oil Treating

Much of the kerosine marketed today is treated by the doctor-treating method using sodium plumbite

TABLE 10[19]

Iron Tetracarbonyl added, grams/gallon	Doctor Test	Percent Mercaptans	ASTM Octane Value
1.2	Sour	0.0150	63.6
2.8	Sour	0.0092	65.7
5.6	Slightly Sour	0.0018	66.7
7.2	Sweet	0.0000	68.2

solution. Both continuous and batch systems are used. Odor, color, and color stability are improved.

Diesel fuels and furnace oils, depending upon whether they are cracked or straight run usually are washed only with strong caustic solution and water to remove organic acids. If they contain cracked materials, the caustic wash may be preceded by sulfuric acid treating. The final water wash sometimes is followed by dehydration by passing the oil through a tower filled with rock sodium chloride or calcium chloride.

Lubricating Oil Treating

The fractions of crude oil which go into the production of lubricating oil must be treated to remove corrosive compounds, gum-forming substances, waxes and asphaltic materials. The treating is necessary because of the variety of duties to which lubricants are applied. Petroleum lubricants are used to reduce friction on all types of machinery, from delicate watches to loose fitting bearings of lumber wagons.

The removal of sulfur compounds, unsaturates asphalt and asphaltenes is accomplished by means of sulphuric acid treating in batch agitators. More modern methods employ mechanical agitation and contactors followed by centrifugal separation of the acid sludge. The oil is then neutralized with lime, caustic soda or ammonia.

The color is improved and foreign materials removed by percolation filtration in which the oil passes down through a bed of fuller's earth, or by the clay contact process, in which finely divided filter clay is intimately contacted with the oil at elevated temperatures, and then removed from the oil by means of pressure filtration.

There are two kinds of wax found in lubricating stocks. Paraffin crystalline wax is associated mostly with the lighter hydrocarbons in the lubricating oil cut. They are present in the lubricating oil distillate. Micro-crystalline wax or amorphous wax is associated with the heavier distillates and residuum stocks. The crystalline wax is removed by chilling to a temperature low enough to crystallize the paraffin, and then filtered through filter presses. The residual wax is removed by chilling and settling the stock after its viscosity has been reduced by blending with a low-boiling naphtha. Settling methods are now practically obsolete, having been replaced by centrifugal methods and solvent refining methods.

The removal of asphalt and wax by solvent methods have replaced many of the older processes.

Asphalt is removed by the use of liquid propane. The oil is mixed with propane under pressure. A sharp separation between the oil-propane mixture takes place. The good oil and propane is then recovered by distillation of the oil-propane layer. Other solvents in the service of dewaxing processes are: petroleum naphtha, propane, benzol-ketone, benzol-acetone, and methyl-butyl-ketone.

Duo-Sol Process

Two practically immiscible solvents, propane and "Selecto" (a blend of phenol and cresol) are intimately contacted with the lubricating-oil fraction. The propane dissolves the desirable paraffinic hydrocarbons and the "Selecto" dissolves the undesirable unsaturated and asphaltic hydrocarbons.

The contact of the oil with the solvents take place in a seven-stage counter-current extraction system with propane extraction taking place in the first three stages, and "Selecto" extraction in the last four stages. Extraction temperatures range from 100° to 150° F. and at pressures sufficient to keep the propane in the liquid phase.

Recovery of the solvents take place in recovery towers operated at 250 psi for the propane, and 5 psi for the "Selecto." Steam is used for stripping and is generated with the use of process heat.

The process eliminates the need for sulfuric acid treatments and yields a lubricating stock of good quality with respect to viscosity index (low change of viscosity with changes in temperature).

Furfural Process

Furfural or furfuraldehyde is a refining solvent which has a high selectivity for lubricating-oil impurities. In the Furfural Process, the solvent is contacted counter-current to the lubricating stock in a column packed with raschig rings. Extraction temperatures, depending upon the nature of the oil being treated, range from 110° to 200° F.

The high specific gravity of furfural (1.16) makes it easily separated from the lower gravity oil. Its boiling point of 323° F. permits recovery in conventional distillation equipment.

Phenol Process

Phenol and untreated oil are contacted intimately by counter-current mixing in an absorber tower. From the top of the tower extracted oil raffinate containing some phenol is removed through a heater to a solvent-recovery tower. The phenol is vaporized and condensed. The bottoms from the absorber tower are also withdrawn through a heater to the solvent-recovery tower. Thus, both raffinate and extract are freed of phenol. The degree of solubility of the oil in the solvent is controlled by varying the quantity of water to the solvent.

Auxiliary heat exchanges, strippers, accumulators, pumps and control instruments, facilitate the operations as outlined briefly above.

Other solvents in use for treating lubricating oils include: liquid sulfur dioxide, chlorex, nitrobenzene and crecylic acid.

A number of additives have also been developed which increase viscosity index, wetting properties and the resistance to oxidation.

BIBLIOGRAPHY

[1] Hawthorne, W. P. and Bedell H. L. "Removal of Inorganic Salts From Crude Petroleum," Refiner and Natural Gasoline Manufacturer, June, 1938, page 260.

[2] Stenzel, R. W. and Research Staff "Salts In Petroleum," Petroleum Rectifying Company.

[3] Horne, J. W. & Christianson, Lloyd F. "Determination Of Total Water Soluble Chlorides In Petroleum," Bureau of Mines Report of Investigations 3517, June, 1940.

[4] Davis, L. I., Jones, J. M. and Neilson, C. A. "Laboratory Control ——— of Desalting Processes," Refiner and Natural Gasoline Manufacturer, June, 1938, page 271.

[5] Anonymous—"Desalting Unit Operation at a Michigan Refinery," Refiner and Gasoline Manufacturer, May, 1937, page 206.

[6] U. S. Patent No. 1,984,903.

[7] Dow, D. B. "Oil Field Emulsions," U. S. Bureau of Mines Bulletin 250.

[8] St. Hill, T. N. and Hanson, G. B. "Extraction Of Salt From Refinery Stocks By The Electrical Process," Refiner and Natural Gasoline Manufacturer, October, 1937, page 466.

[9] Anonymous—"Desalting Crude By The Electric Process," The Petroleum Engineer, June, 1943, page 114.

[10] Kirkbride, C. G. "Desalting Of Petroleum With Fiberglass Packing," Petroleum Refiner, July, 1946, page 95.

[11] Anonymous—"Novel System For Removing Hydrogen Sulfide From Distillates," Refiner and Natural Gas Manufacturer, December, 1938, page 80.

[12] U. S. Patent Nos. 1,945,163; 2,110,403; 2,157,879.

[13] Bottoms, R. R. and Wood, W. R. "The Girbotol Purification Process," Refiner and Natural Gas Manufacturer, March, 1935.

[14] Happel, John; Cauley, S. P.; and Kelly, H. S. "Critical Analysis Of Sweetening Processes and Mercaptan Removal," Petroleum Refiner, November, 1942, page 102.

[15] MacKusick, B. L. and Alves, H. A. "Mercapsol Process For Gasoline Treating," Oil and Gas Journal, April 13, 1944.

[16] Field, H. W. "Caustic-Methanol Mercaptan Extraction Process," Refiner and Natural Gasoline Manufacturer, October, 1941, page 73.

[17] Anonymous—"Tannin Solutizer Process," Oil and Gas Journal, March 31, 1945, page 190.

[18] U. S. Patent No. 2,354,974.

[19] U. S. Patent No. 2,354,646.

Role of Water in Conquering Fire in Refining Plants

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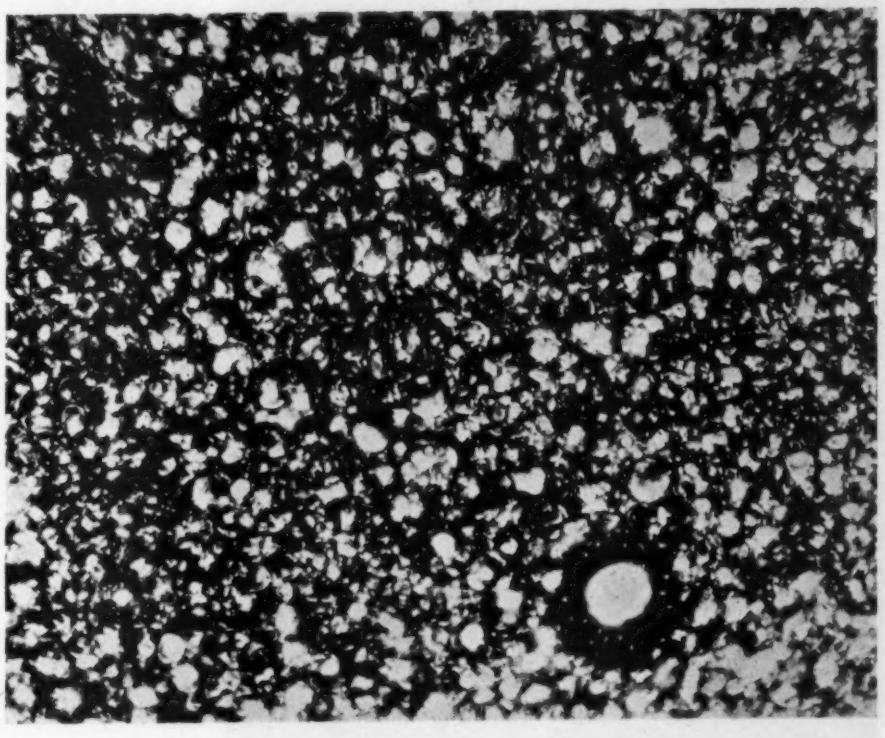
WATER, properly applied, can conquer many of the fires in refinery plants, using equipment already available. Technical advances now taking usable shape should let us say in the near future that water with certain essential assistance will be able to put out almost all or perhaps all types of fire common to refining plants.

Let us look at what already is possible. Water alone can extinguish fires in the heavy and medium oils by the simple process of emulsification at and near the surface of the burning oil. Mixtures of oil and the lighter petroleum fractions, including gasoline and similar liquids, are extinguished almost as easily as long as the percentage of medium or heavy oil in the mixture is sufficient to permit emulsification, for the emulsion itself is fire-extinguishing.



Oil-water emulsion (magnified 100 times) as it is starting to break down into oil and water. The large circular drop near lower right corner is oil separating out and floating on water.

The effectiveness of water in extinguishing oil fires depends on the method of applying it. Turn a solid stream of water on an oil fire and the water promptly sinks to the bottom. The oil, being lighter, floats on top and continues to burn. But disperse the same stream of water into droplets of the proper sizes, drive them at the correct velocities and use this dispersed water to bombard the surface of the oil, and the result is so different as to seem miraculous the first time you see it.

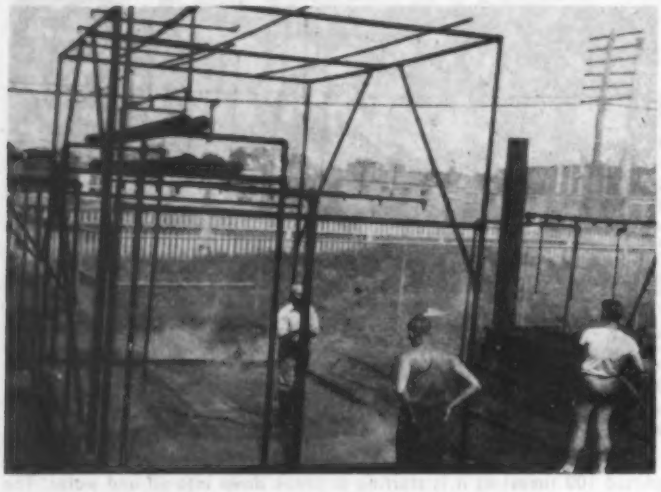
There is dispute about what causes this seeming miracle of extinguishment but some things are beyond dispute. The first thing is that it is possible to form emulsions with oil and water whose effect is fire extinguishing. Not only are the emulsions formed, but they can be observed at the surface of the oil after the fire has been extinguished. Although temporary in nature it is possible to transfer samples of such emulsions to a microscope slide and examine them there, or to photograph them with both still and motion picture cameras. In motion pictures it is possible to study the process in which the emulsion breaks down into oil and water, with the water sinking to the bottom and the oil again floating on top of it.

The process of creating fire-extinguishing emulsions on burning oil is performed in fire fighting by making water droplets of the correct range of sizes, and driven at the correct velocities impinge upon the surface of the burning oil in the form of a spray. If you want to see what a similar emulsion looks like take a test tube or small bottle, fill it a quarter full with water, add oil (lubricating oil works well) to bring the level up to the half-way mark. Then cover the container and shake it violently. When you have formed the emulsion, let it stand and time the interval until the temporary emulsion breaks down into water and oil again. Depending upon the thickness of the film of emulsion formed by spraying, that time interval will give you some estimate of the "safe" interval when an emulsion-extinguished oil fire can be expected to remain free from flash-back danger, for that particular oil. There is a wide range of times that the emulsion persists for the various oils, the time being generally longer the heavier the oil.

Other possible methods of extinguishing oil fires with water alone lack one of the outstanding advantages of the emulsion-forming method: the effect of

Demonstration of Emulsion's Safety From Flash-Back of Fire

Fireman with no special protection except boots takes high-velocity spray against oil-spill fire.



Fire out. Unprotected, fireman chats with onlookers from center of emulsion-extinguished oil covered fire area.

An inexperienced onlooker borrows fireman's hat and coat and, bare-legged, proceeds to show that almost anyone can do it.

minimizing the danger of flash-back in the area of the oil surface where the fire has just been extinguished. This advantage can be of great importance when an oil fire is being extinguished with portable equipment, as in an oil-spill fire, where the area involved is so large it is necessary for the fireman to walk into the oil soaked area in following up the rest of the fire. Leaving a film of emulsion on the oil surface behind him gives him precious minutes of time in which to fight the fire ahead of him without finding himself surrounded by flames from an area that has reignited behind his back.

Fights Fire at Its Base

The outstanding technical distinction between the emulsion-forming fire-fighting technique, and other techniques using water alone, lies in the fact that the emulsion method follows long established fire-fighting practice by fighting the fire at its base. When a fireman approaches a fire in wood or similar material he does not play his hose on the flames. He directs his hose stream onto the wood from which gases are being distilled that are burning as flames. He does this for the same reason that it is the best practice to use water droplets large enough to reach the burning oil fires.

Oil and wood appear to be very different materials, but neither one of them is flammable in its normal condition. Oil and wood both burn with flame only after they have been heated sufficiently to give off a gas or vapor. With either type of material the fire that is being fought is a gas or vapor fire. And the simplest procedure in checking such a fire is to cut off the fuel supply of flammable gases or vapors. The fireman cuts off the supply of flammable gases from wood by cooling the wood with water to a temperature where it can no longer distill off flammable gases. This is easy because wood is a solid and the temperature at which gases and vapors are distilled off is many degrees above the boiling temperature of water. Hence water striking the hot solid is broken up and evaporated, carrying off heat at the rate of over 1000 Btu per pound of water turned into steam, at a temperature level much below that needed for the evolution of more fuel.

Solid Stream Futile

With oil the conditions are entirely different. As already pointed out it is futile to attack such a fire with an ordinary solid stream. With many oils, cooling to a temperature at which flammable gases and vapors will no longer be given off is impossible because the flash and fire points are substantially lower than the boiling point of water. In such circumstances the emulsion-forming method of fighting oil fires puts out the oil fire by covering the surface of the burning oil with a fire-extinguishing emulsion.

As noted before, in the case of fairly heavy oils the emulsion is lasting enough to permit examination on the surface of the extinguished oil or by transfer to a microscope slide. With the lighter oils the emulsion is very fleeting and exists only so long as droplets are impinging upon the surface. This is long enough to extinguish the fire, but after the fire is out there is no visible trace of an emulsion on the oil surface. This fact has led some observers to discard the emulsification theory of oil-fire extinguishment in favor of the theory of extinguishment by cooling where they become entangled in inescapable contradictions.

Droplets vs. Fog

The two schools of theories disputing about how oil fires are put out battle most loudly about the size of water particles which are most effective, and how they should be used. Practical users of equipment for producing both the water-droplet sizes of dispersed water and users of equipment for producing so-called "fog" or atomized water are putting out fires that were believed impossible to extinguish with water not many years ago. The droplet advocates cool from the base of the fire while the "fog" advocates claim to cool first the flames and then the base of the fire.

The fact of prime importance to the user is that the oil fires go out. How they are extinguished is of great importance in research efforts to improve and extend the use of dispersed water for putting out fires in the lighter oils and flammable liquids. It is only fair to note here that the physical and mechanical difficulties of dispersing water, in fire-extinguishing quantities, make it impossible to produce either droplets or "fog" particles of uniform size. And even some of the "high-pressure fog" apparatus emits droplets of emulsion-forming sizes and velocities.

Since a good fight is interesting to most everyone, let us look at some of the other points in dispute. Both droplets and "fog" must be discharged upon a fire from closer range than is necessary with a solid stream. But just as you can throw sand farther than you can throw dust, it is possible to throw droplets farther and straighter than you can throw atomized water. This gives the fireman using droplets an advantage when it is necessary to fight an oil fire with a strong wind or heat draft blowing across the path of the water discharge. Droplets permit the fire to be fought from a slightly safer and more comfortable distance.

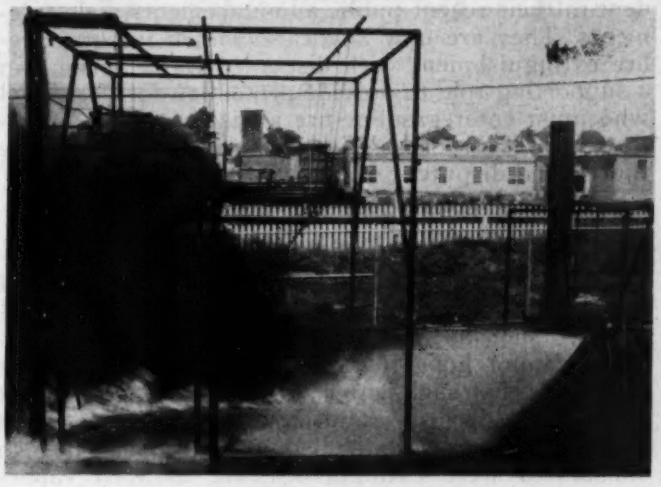
An important point to the user is the pressure necessary to use the two competing systems. Effective dispersion of water into droplets for oil-fire fighting can be obtained at 75 pounds per square inch and upward. Well dispersed "fog" requires pressures from 100 pounds up and the advocates of extreme atomization are using pressures from 600 to 1000 pounds per square inch. The dispersion of water takes large amounts of power used to create pressure, and the comparative costs of the two methods merit consideration.

Water Required

Another point of dispute is how much water is necessary to put out an oil fire. It takes a very few gallons of water correctly dispersed into the right size droplets and driven at the correct velocities to cover the surface of an oil fire with a fire-extinguishing emulsion. It takes a great many more gallons of water evaporated or turned to steam in the flame zone above an oil fire just to balance the heat-output of the fire, and still more gallons to produce any cooling effect at the surface of the burning oil.

The most important point of dispute concerns the comparative danger of clogging in the competing methods of producing droplets and "fog." In an effort to produce a large proportion of "fog" very small holes are used to start the dispersion of the water. These small holes are subject to clogging from sand, scale, rust and similar impurities which are apt to be present in fire fighting water supplies. To get out of this trouble a screen is placed upstream from the "fog" tip or head, but the screen is in turn

Heat Protection Furnished by Spray-Filled Discharge Cone



Start of attack upon an oil-spill fire. Notice flame retreating before film of emulsion driven ahead of spray.

Fireman walks into oil-covered area protected against flash-back by emulsion remaining on oil after extinguishment.

Fire all out. Notice tank containing kerosine at left, protected during fire by fine droplet, low-velocity spray.

subject to clogging from the same cause. The water droplet advocates have found it not necessary to use small holes or screens and provide openings large enough to pass all ordinary water-borne debris.

In regard to putting out gasoline fires some of the more vocal advocates of "fog" claimed to be able to do it and advised it, based upon faulty conclusions from inadequate tests. A more cautious tone is evident in their recent public announcements and statements. They are now advocating foam for gasoline-fire extinguishment with dispersed water serving in a supporting role to provide protection for personnel who must enter gasoline-fire areas for rescue or extinguishing purposes. With this more recent attitude there is no dispute.

Controlled Burning of Explosive Hydrocarbons

Recent changes in refining processes and the demands of the synthetic-rubber industry have turned refineries to the production of flammable volatile substances, such as butadiene, that water, as now applied, cannot hope to extinguish once it has burst into flame. For such materials it has been found most practical to dispose of the escaped substance which has caught fire by controlled burning. Even if such substances were extinguished, the escaped vapors when mixed with the right proportion of air would form explosive mixtures capable of greater damage than fire.

For controlled burning, sprays of finely divided water droplets have proven both effective and practical. They are projected so as to maintain a covering film of water over all surfaces of tanks, pipes, structures and equipment exposed to the heat of volatile liquid fires. This fine-droplet spray protects them from serious distortion and buckling while the escaped liquids and vapors are permitted to burn up. Where such volatile materials are stored under pressure in tanks, these sprays have proven able to limit heat transfer to the material inside the tank to a level where the safety vents, generally provided, can take care of the increased vaporization without danger of explosion and bursting of the container.

In applying dispersed water for conquering fire in refining plants fixed equipment, automatically put into action, deserves serious consideration for two obvious reasons. First: the manpower necessary for successful operation of portable hose lines and the necessary training facilities for the fire fighting squad are not generally available. Second: the types of crude or refined, fire-hazard materials are fairly definitely segregated and, knowing the characteristics of the flammable material in advance, it is a simple matter to specify the water droplet sizes, velocities and quantities which experience has shown to be most effective in putting out or controlling fire in such material.

The general principle in applying water sprays to create fire-extinguishing emulsions is to use droplets in the larger range of sizes at high velocities for the heavier oils and droplets in the smaller range of sizes at lower velocities for the lighter oils and kerosine.

Portable Equipment

Portable equipment deserves serious consideration in all locations where enough men are on duty regularly to handle it and in locations where a variety of flammable materials are located. With portable equipment such as the 1½-inch "Flame Buster" and its accompanying applicator which can be effectively handled by one man, three forms of water, two of them dispersed, are almost instantly available. The operator need simply move an easy-acting valve handle to change from a solid stream to a high velocity spray. By substituting a low-velocity applicator with spray tip for the high velocity spray tip he gets a choice of solid stream or an umbrella-shaped cone of low-velocity spray centered from 4 to 10 feet in front of him for protection during approach and to put out or control the fire.

Use in Electrical Industry

The emulsion-forming technique has been used successfully in the electrical industry to put out oil fires for a decade or more. One of the worst hazards around transformer stations and sub-stations is from oil fires starting in transformers. The transformer oil used for insulation and cooling in large transformers may become heated from arcing between the windings inside the transformer or between the windings and the case when the insulation breaks down. Arcing or a lightning stroke may ignite the oil. Although spoken of as a Class C fire, what results is generally an oil fire or a Class B fire. Fixed installations producing the correct water droplet sizes and velocities are automatically set in operation when such fires occur and the fires are extinguished almost instantaneously. Water spray is electrically non-conducting even when played upon high-tension live conductors. As a result of proven success over twenty million kilo-volt-amperes of transformer capacity are already protected by such "Mulsifyre" installations in the United States alone.

For reasons known only to themselves, oil refinery men have made few inquiries about the effectiveness of water alone in putting out oil fires. As early as 1936 the United States Navy conducted successful tests of the emulsion-forming technique in putting out oil fires aboard war vessels. These tests were run at the navy yard in Philadelphia using the decommissioned U.S.S. Rowan as a full-scale testing laboratory. Oil fires started in the bilge, under the floor plates of the engine room and including heated oil sprayed against the boiler fronts from a slit pipe, were extinguished in a matter of seconds after the emulsion-forming dispersed water discharge was started. One fire was permitted to burn freely until the plates on the top deck began to buckle. A seaman walking across the plates had the rubber soles and one of the heels of his shoes melted off from the intense heat, but this fire, like the others went out in a matter of seconds. It seemed to some observers that the hotter the fire, the quicker the extinguishment by the emulsion-forming method.

The Navy later installed emulsion-forming spray equipment to cope with oil fires in the original U.S.S. Helena, the original Aircraft Carrier Wasp and the light cruiser U.S.S. St. Louis. The latter has recently been decommissioned, while the other two ships have been sunk in battle action not involving oil fires in protected areas, so far as we know.

Tests so far conducted by the oil and refining industries have not included full-scale fire tests of emulsion-forming water sprays. In that statement is a suggestion to some organization having the necessary facilities and water supply to make them available for supervised tests to demonstrate a proven method of extinguishing oil fires that has been long overlooked by the industry most concerned and most able to benefit from it.

Cetane Number of Diesel Fuel From Average Boiling Point and Density by Nomograph

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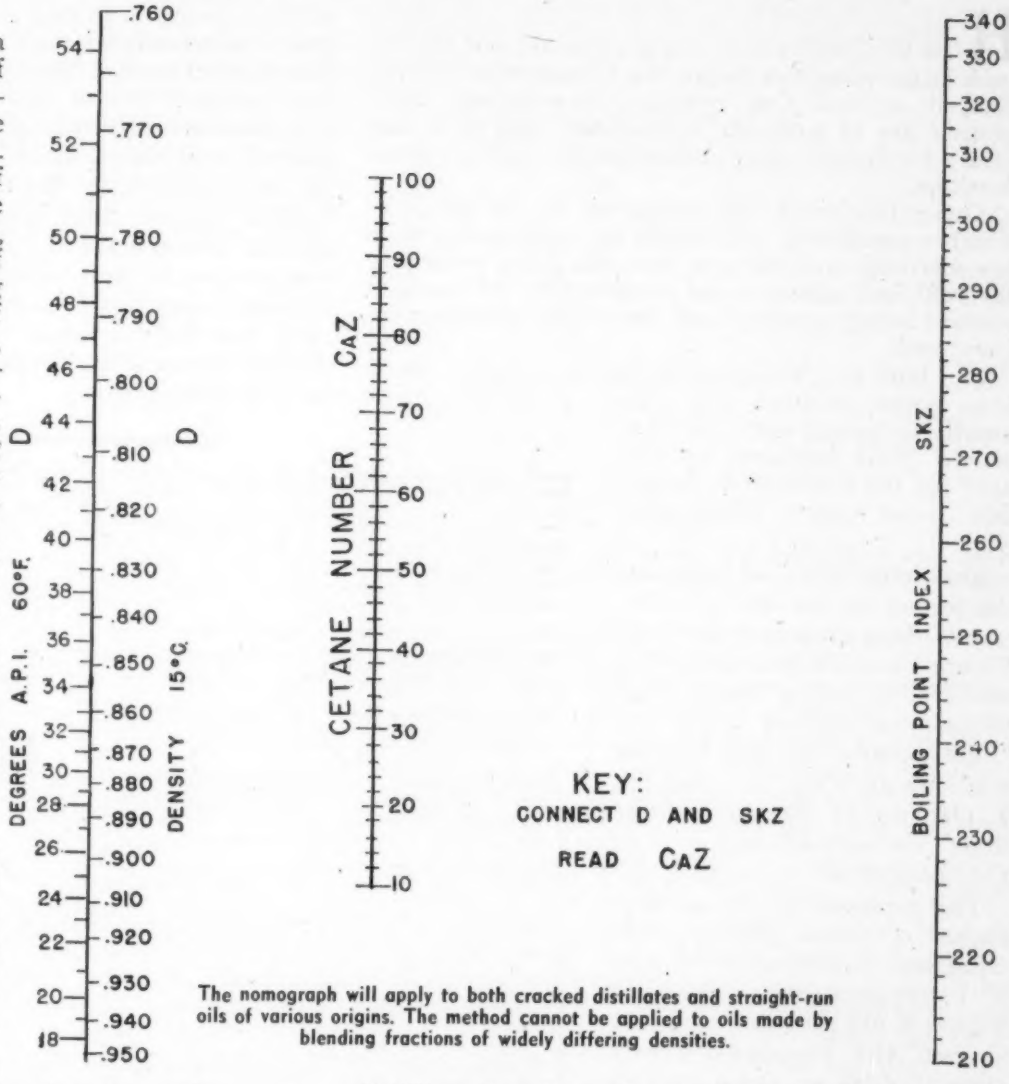
THE cetane number, a measure of the ease of ignition, is the most important constant for the evaluation of diesel fuel. With the development of diesel engines which have specific fuel requirements, and with the diversity of type of fuel oils resulting from the diversity of source, such as petroleum, coal, Fischer-Tropsch syntheses, special hydrogenated oils, etc., there has come a demand for a rapid method for characterization of fuel oils with respect to their ignition and knock characteristics. Various types of test engines have been developed but all of them have the disadvantages of high cost and lengthy test period. As a consequence, many laboratory procedures have been advanced. Of these, the method of Marder[2] as extended by Vorberg[3, 4] has a wide range of use. It may be applied to diesel fuels of any origin or boiling range except those the components of which have widely different densities, such as kogasin and coal-tar distillates. It cannot be applied to oils containing anti-knock compounds.



The nomograph will apply to both cracked distillates and straight-run oils of various origins. The method cannot be applied to oils made by blending fractions of widely differing densities.

It had been shown by Boerlage and Broeze[1] that the ease of spontaneous ignition of hydrocarbons is proportional to the molecular weight and, therefore, to the boiling point of the oil. Marder[2] postulated that the density of an oil indicates its paraffinic or aromatic nature. He developed a method using density and boiling point for determining cetane numbers from relative cetane numbers which were obtained in the old CFR-test engine using the throttle method.

In the method outlined by Vorberg[3, 4] the density and the boiling point index (SKZ) are combined in empirical equations to give cetane numbers which, over a wide range of fuels, are in close agreement with values determined by the ignition method.

The boiling point index (SKZ) is determined by distilling the oil in the standard distillation apparatus according to ASTM method as follows: the temperatures at which 5 percent, 15 percent, 25 percent, etc., and 95 percent have distilled off are added and divided by 10. In the case of very-high-boiling oils distillation is stopped when cracking (according to ASTM definition) starts and the temperatures of the cuts taken are averaged.

The data given by Vorberg have been assembled into the nomograph. To find the cetane number of a fuel having a density of (for example) 0.870 at 15° C. and a boiling-point index of 247, connect 0.870 on the D scale and 247 on the SKZ scale and read the cetane number, 30.5 on the CaZ scale.

REFERENCES

[1] Boerlage and Broeze. V.D.I. Test Methods No. 336 (1934).
[2] Marder Brennst. Chemie **16**, 286 (1935).
[3] Vorberg Oel u. Kohle **39**, 847 (1943).
[4] Vorberg and Barth, Petr. Ref. **24**, 394 (1945).

Manufacturing Methods and Tests On Hub-Wedge and Curve Greases As Used on Railroad Equipment

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HUB-WEDGE and Curve greases are not used in such large quantities as are the Locomotive Driving Journal or Rod Cup greases, nevertheless, these greases are of sufficient importance that it is necessary for them to meet certain specific railroad specifications.

These lubricants are subjected to all kinds of weather conditions, and should be compounded from low-viscosity and low-pour-test oils. They must posses sufficient adhesion and suitable film thickness to prevent being squeezed out, due to the pressures encountered.

The Hub and Wedge lubricant is a straight lime-base grease without any fillers or additives and usually is applied with a wooden paddle. This lubricant is also used for the lubrication of traction motor gears (diesel-electric).

The importance of selecting the proper oil for the manufacture of these greases is shown in Figure 1 and Table 1. Oils No. 1 and No. 3 having the lightest viscosity are best used for "light" grades or cold-weather applications, while No. 2 and No. 8 oils may be classed as "medium" viscosity oils and No. 7 as the "heavy" oil.

The penetrations or consistencies of these greases were made and plotted at 77° F. and 0° F. temperatures as shown in Figure 2. On the same chart are shown the pressure-viscosity curves of these three greases taken at various temperatures. The grease having a medium flat pressure viscosity curve, represents the most suitable product for an all-year lubricant.

The oils used in these greases were first tested as to their pour point and channeling. The channel tests of these oils are shown in Figure 3, made at temperatures from —38° F. to +40° F. and represent and illustrate the six oils tested for the purpose of ascertaining which one of these oils would be the most suitable for the manufacture of an all-year residual grease. The channel curves show actual channel temperature and fluidity index. The channel temperature is the temperature at which a one-inch channel closes in 20 seconds after the one-inch steel strip has been pushed through the grease. The Fluidity Index is the temperature range from 2 to 200 seconds closing time.

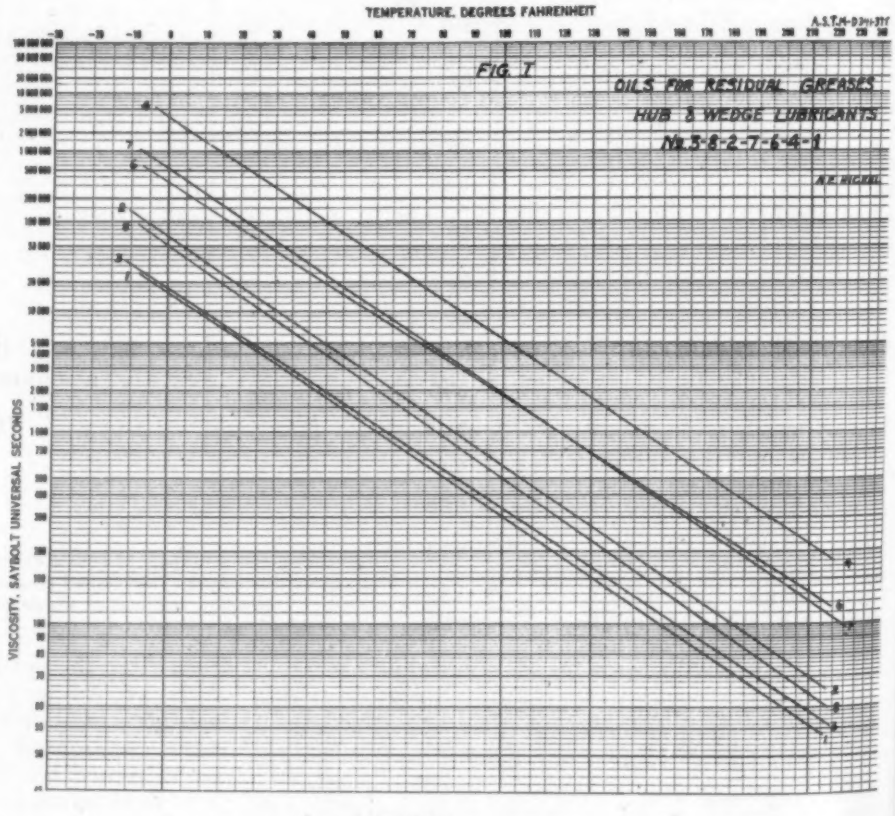


FIGURE 1

TABLE 1

OIL No.	Vis. 0 °F.	Vis. 100 °F.	Vis. 210 °F.	Pour Actual	Vis. Index	Channel Temp.	Fluidity Index	L.M. Hy.	Remarks
3	17,500	475	58.5	—20 ° F.	74	—31 ° F.	19	L	Small amount soft asphaltic matter.
8	52,000	706	62	—15 ° F.	40	—24 ° F.	28	L	Small amount soft asphaltic matter.
2	60,000	819	71	—15 ° F.	67.4	—21 ° F.	30	M	Medium amount of soft asphaltic matter.
7	500,000	2428	121	—0 ° F.	65.2	—8 ° F.	26	Hy	Medium amount of soft asphaltic matter.
6	320,000	2267	125	+30 ° F.	78	—4 ° F.	22	Hy	Very small amount of asphaltic matter but heavier oil.
4	3,500,000	6757	210	+25 ° F.	62	+5 ° F.	54	Hy	Large amount of soft asphaltic matter.
1	17,000	464	55	—20 ° F.	51.4	.....	..	L	Small amount of hard asphaltic matter.

Composition and some physical tests of three Hub and Wedge greases, made with the No. 3, No. 2 and No. 7 oils are shown in Table 2.

Railroad Curve Greases

The Curve grease which is also a lime-base grease contains a specified amount of high-grade floculated or micronized graphite, which not only gives it greater adhesion, but extreme pressure properties to stand up under the high pressures encountered.

This grease is used and applied by means of a rail and flange lubricator and there are a large number of these lubricators now in use. They are located alongside the track and near the curves of the roadbed. The lubricant is pumped automatically from a permanently installed lubricator by means of a ratchet and cam assembly, actuating a pump, which delivers a specified amount of the grease in a bead form to the side of the high rail on curves by means of a specially perforated feed bar, from where it is picked up by the wheel flange and distributed over the contact side of the rail. The grease film thus produced reduces the pressure and wear on the rail and flange of the car wheels, especially on the high rails on curves. On ordinary curves, the pressure is not as great as on curves located on steep grades, and downgrade curves, with continuous breaking.

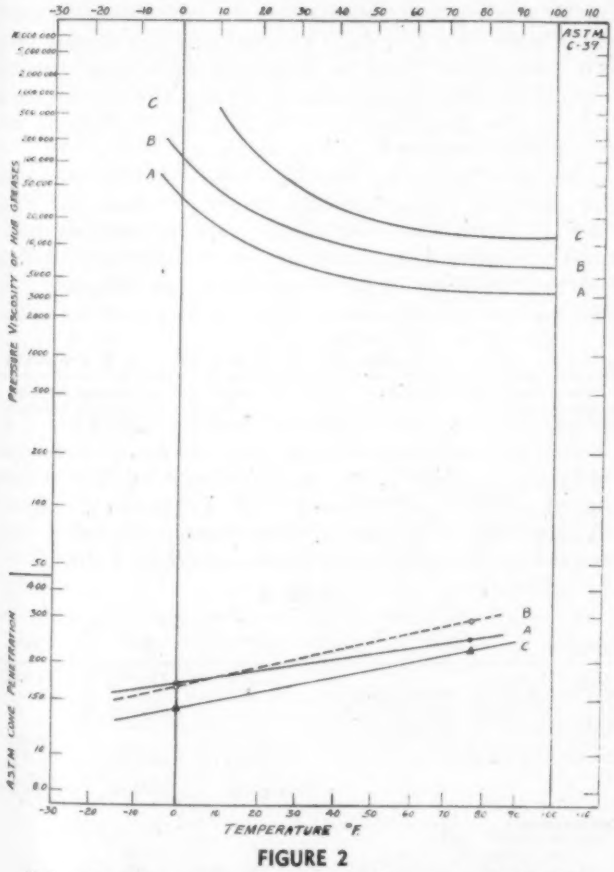


FIGURE 2

Hub and wedge greases. Upper curves show pressure viscosity, lower lines show ASTM penetration.

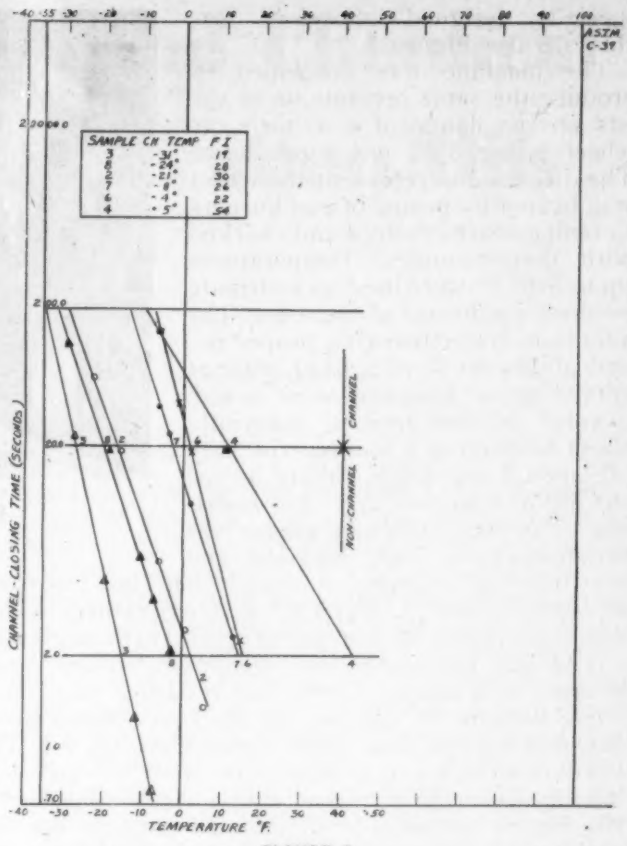


FIGURE 3

Oils for all-year residue greases; hub and wedge lubricants, also traction motor gears. Channel curves show channel temperature and fluidity index.

Old and worn equipment is very severe on curves, causing pressures up to 500,000 to 800,000 psi. under heavy loads. The Curve grease therefore, must have high heat-resisting characteristics and in combination with 10 percent graphite specified by the railroads, will protect the rails and wheel flanges against excessive wear.

The consistency of a year-round Curve grease is important, for it must be soft enough to be delivered to the side of the rail at —10° F. or lower, it must not spread on top of the rail and must be water resisting. At the summer temperatures, it must adhere to the rail, especially under high temperatures caused by wheel breaking. It must be sufficiently adhesive at these temperatures to adhere to the hot flange when it will be carried along the railhead for a considerable distance. To obtain a satisfactory lubricant which will meet these conditions, it was necessary to make four different products which were tested on a

TABLE 2

SAMPLE	ASTM Grade	Percent Cal. Soap	Percent Rosin Soap	Vis. 100 °F.	Vis. 210 °F.	Actual Pour	ASTM Cone Penetration	Freezing Test	Bleeding Test
No. 3 oil	3	18.04	1.57	475	58.5	—20 ° F.	as is 216 wkd. 249 at 0 ° F. 172	O.K. —40 ° F.	24 hr.—120 ° F. none 24 hr.—150 ° F. none 48 hr.—160 ° F. 5 percent
No. 2 oil	2	20.83	2.09	819	71	—15 ° F.	as is 233 wkd. 286 at 0 ° F. 170	O.K. —35 ° F.	24 hr.—120 ° F. none 24 hr.—150 ° F. none 48 hr.—160 ° F. 1 percent
No. 7 oil	3	20.25	2.07	2428	121	—0 °F.	as is 219 wkd. 230 at 0 ° F. 141	O.K. —22 ° F.	24 hr.—120 ° F. none 24 hr.—150 ° F. none 48 hr.—160 ° F. 5 percent

Sample with No. 3 oil—Best all-year product.
Sample with No. 2 oil—Satisfactory all-year product.
Sample with No. 7 oil—Summer only.

specially designed laboratory machine as per Figure 4.

The machine was developed to produce the same revolutions as exists on the flange of a 32-inch car wheel going 39½ miles per hour. The disc used to represent the wheel was heated by means of gas burners to temperatures desired and checked with thermocouples. Temperatures up to 500° F. were used to anticipate severest conditions of operation. The adhesion, water-resisting properties, and ability to form a bead without spreading or creeping were noted. Several of the greases, especially those containing a too-low-viscosity oil, spread too much, others lacked sufficient adhesion and heat-resisting properties. Only one grease was satisfactory in both adhesion and heat-resisting properties. A special "drip" test was made at 100° F., 125° F. and 150° F. temperatures which was used to check the heat test as applied to these greases.

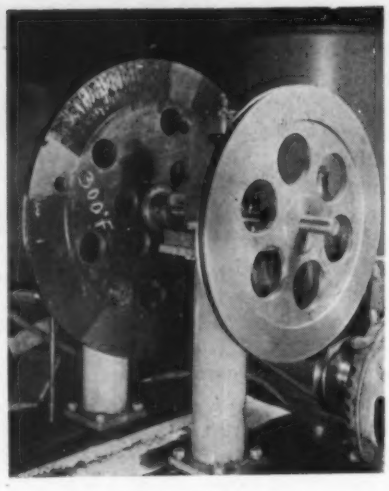


FIGURE 4

The heat and water tests demonstrated that some greases lack adhesion and heat-resisting properties, while sample "A" seems to be the best all-year product, due to containing the higher-viscosity oil. The lower viscosities in samples "D" and "C" although having flatter penetration curves, lack adhesion at the higher temperatures. Channel tests on the oils used and penetrations of the finished greases represent the fluidity to the pump, while the pressure-viscosity curves at three different temperatures represent the viscosity of the lubricant in the feed pipe from the pump to the rail head.

Graphite, because of its softness and unusual greasiness, coupled with its chemical inertness, is the ideal additive to produce extreme pressure properties in Curve greases. The adhesion or affinity to metals and other materials, of the flocculated or micronized graphite, is due to its surface energy; therefore, when such graphite is adsorbed to a metallic surface it forms a bond of great tenacity. Graphite is also a good conductor of heat and electricity and its temperature of fusibility is unknown, but may be around 3000° C.

The average percentage of graphite usually incorporated in a lubricant varies from 1 to 10 percent. The addition of 4 percent of graphite to an oil has shown best results, however, graphite up to 8.5 percent will assist in reducing the coefficient of friction. For heavy loads and pressures it was found that 10 percent of graphite incorporated in a calcium grease will give satisfactory performance under very high pressures. Such a product will have greater wetting properties and adhesion than the same grease without the graphite, and its film or coating is not very easily removed.

The pour point of the oils used in the manufacture of these Curve greases ranged from —65° F. to —20° F., with low viscosities, which necessitated a small amount of extreme-pressure additive, such as 1 percent sulphur or other additives, as follows:

	Vis. Sus./100 °F.	Pour Point	E. P. Properties
Sample A—oil	475	—20 °F.	1 Percent Sulphur
Sample E—oil	111	—25 °F.	1 Percent Sulphur
Sample D—oil	64	—65 °F.	Light E. P.

Figure 5, shows the penetrations of five Curve greases at 77° F., 0° F.; and —22° F. Due to the lack of adhesion, film thickness, etc., on samples B and C, only samples A, E and D will be described in Table 3.

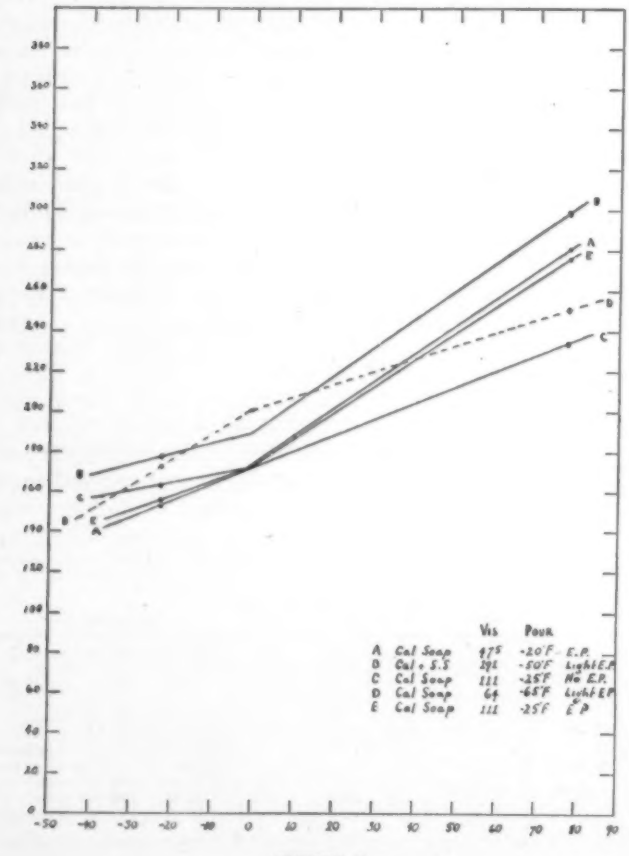


FIGURE 5
Curve grease penetration at 77° F., 0° F., —22° F.

TABLE 3

Samples	"A"	"E"	"D"
Calcium Soap	17.58%	17.15%	17.50%
Oil 475 SUS/100 °F. plus 1% Sulphur	72.42%	.....	.....
Oil 111 SUS/100 °F. plus 1% Sulphur	.....	72.85%	.....
Oil 64 SUS/100 °F. plus light E. P. additives	.....	.....	72.50%
Micronized Graphite	10.00%	10.00%	10.00%
	100.00%	100.00%	100.00%
Penetration:			
ASTM—D217—44T:			
Cone unworked	219	239	232
Cone worked	280	275	251
Cone at 0 °F.	172	172	201
Cone at —22 °F.	154	157.5	173
ASTM—D55—44T melting point	224 °F.	215 °F.	215 °F.
SAE film strength of oil used	390-750 rpm.	390-750 rpm.	390-750 rpm.
	550# 215#	385# 210#	385# 70#
SAE film strength of grease	465# 180#	426# 225#	245# 75#
Channel test of oil used	—31 °F.	—46 °F.	—80 °F.
Freezing test of grease	O.K. to —50 °F.	O.K. to —50 °F.	O.K. to —50 °F.

Properly applied and used, the Curve grease produces a great saving in labor, equipment and repairs, and permits increased train tonnage. The effect of the lubricators when used in connection with the right grease, will reduce wear on the high rails of curves, and on the outer rails at turnout leads, as has been shown by the increase in mileage between the turning of the wheels, from normal 20,000 miles to more than 60,000 miles, after installation of the lubricators.

Physical Properties and Chemical Constitution of Lubricating Oils

DR. M. FREUND

Translated from "Petroleum Zeit." XXXI, No. 19, by E. J. Barth, Petroleum Technologist

IN THE STUDY of the physical and chemical properties of lubricants it is of first importance to compare oils whose viscosities are identical at either 100° F, 122° F, or at 210° F. These temperatures were chosen as presenting practical working temperatures in industrial applications, this series of temperatures lies within the range of convenient laboratory procedure and appears to be the most convenient to use.

With this as a basis we selected samples which were divided into three groups for the purpose of this investigation. These samples had previously been used in the author's researches[5]. The lubricants in any one group show the same viscosity at 50° C. (122° F); in group A, for instance, viscosities range from 4.1 to 4.6 Engler degrees; group B viscosities range from 10.9 to 11.5 degrees, and in group C between 21.9 to 22.9 degrees. All samples were commercially refined oils. The results of physical tests of the oils in each group are tabulated in Table 1, arranged in order of increasing specific gravities. At the top will be found the lightest oils, namely, the "paraffinic" oils, such as Pennsylvania oils which are next followed by the oils of "mixed-base" character. With increasing tendency toward naphthenic character the lowest series are oils of asphaltic base origin, such as the Texas and Roumanian products.

Table 1 shows physical-chemical characteristics of the oils mentioned previously. In column 1 is given the viscosity at 50° C. in Angler degrees; column 2 shows the specific gravity at 20° C. column 3 shows the pour test[1]; column 4 the absolue viscosities in centipoises at 30, 50, 100 and 200° C (by Vogel viscosimeter); column 5 shows the viscosity-gravity constant according to Hill and Coates[2]; and in column 6 the viscosity-index by Dean and Davis[3]. In column 7 are shown the average boiling-points and the 90 percent boiling-point derived by vacuum distillation made at 0.1 mm; column 8 shows the Conradson carbon residue[4]; and finally, in column 9 the sludge formation test when oxygen is led into the oil for 10 hours at 200° C. This oxidation was conducted in a special apparatus using 60 cc. of sample, and running all samples in each group during the same day and under similar atmospheric conditions. In a previous contribution[5] the author described the laboratory procedure used in obtaining the results shown in Tables 1 and 2.

Using this method of grouping the oils, it appears at once that comparing oils of equal viscosity the specific gravity appears to be characteristic and indicative of many of the other properties of such oils. One notices that in column 4, Table 1, the viscosity curves become steeper with the increase in specific gravity, and that the absolute viscosity at 200° C becomes increasingly smaller. The calculated V.G.C. from the data (column 5), the V.I. (column 6), and the many other common constants—some of which may at present bear no commercial significance—also behave and group themselves with a quite significant uniformity.

It is therefore clear that if one desires to characterize an oil as to its behavior at the higher temperatures (50-200° C.) it will suffice to specify, say the

TABLE 1

GROUP	Sample No.	Viscosity 50 °C. °E	Spec. Grav. 20 °C.	Pour Point °C.	Abs. Viscosity at °C. in Centipoises				Sp. Gr. Visc. Constant	V. I.	Boiling Point at 0.1 mm. °C.		Con. Carbon Percent	Oxidation Test Percent Sludge
					30	50	100	200			90 Percent Dist.	Average		
		1	2	3	4				5	6	7		8	9
A	C-34	4.08	0.875	−3	64.6	25.7	5.68	1.77 (170°C.)	0.814	76	....	....	0.32	....
	C-35	4.19	0.902	+8	75.3	25.5	5.51	1.72	0.851	32	....	....	0.11	....
	C-33	4.56	0.932	−10	99.3	31.3	5.4	1.60	0.892	−65	....	....	0.16	....
B	S-29	11.15	0.881	0	206	69.4	11.8	2.00	0.807	−100	390	287	0.24	0.50
	S-111	11.46	0.890	−2	222	72.8	11.68	2.06	0.817	99	314	256	1.0	0.78
	S-32	11.32	0.902	−5	237	71.7	10.6	1.84	0.835	86	343	261	1.14	2.25
	D-4	10.90	0.931	−2	317.4	73.8	9.71	1.60	0.876	5	268	234	0.20	....
	S-20	10.96	0.938	−13	257.4	73.2	8.99	1.60	0.888	17	278	233	0.44	5.17
C	S-28	22.65	0.886	0	481	144.4	19.65	2.93	0.804	103	390	328	1.71	0.69
	S-100	22.90	0.888	−8	485	145.	19.8	2.84	0.806	103	372	309	1.37	0.0
	S-62	22.60	0.892	−8	477	141	19.14	2.56	0.812	100	390	321	1.37	0.0
	S-5	22.08	0.910	−4	564	150.6	17.34	2.26	0.837	75	368	289	1.02	2.34
	S-96	21.91	0.913	−7	558	139.6	16.1	2.30	0.842	63	326	276	1.31	3.33
	S-51	22.85	0.914	−5	539	140.	16.9	2.15	0.844	59	355	274	1.05	3.80
	S-115	22.44	0.934	+1	701	148.7	15.5	2.05	0.872	33	314	254	0.78	9.33
	S-40	22.60	0.935	−8	726	154.5	15.6	1.96	0.875	7	285	260	0.55	7.77
	P-4	22.53	0.947	−11	780	158.5	14.6	1.85	0.890	22	280	214	0.43	....

specific gravity and one viscosity, at a given low temperature such as the viscosity at 50° C. At lower temperatures the viscosity data is considerably altered and affected by separation of waxes, especially with the truly "paraffinic" oils. However, modern dewaxing methods obtaining low-pour oils has solved the problem of the separation of wax during laboratory testing at reasonably low temperatures, though this again is quite relative. The pour point of an oil is therefore of great importance when determining a series of low- to medium-temperature viscosities.

Mention should be made in this connection that special additives often are added in small amounts to many waxy oils in order to reduce the pour point, and such additions affect at times also the properties other than the pour point; some pour-depressors greatly affect viscosity-index and even the oxidation stability.

Of significance also in Table 1 are the results of the vacuum distillation made at 0.1 mm. pressure. One will notice that oils of low specific gravity(high Beaume or "light") show the highest boiling-point. They boil higher than oils which follow them in the same group and which show a greater or a heavier specific gravity. For instance, the boiling-point at 90 percent off of the Pennsylvanian oil is approximately 100° C. higher than the boiling-point of the Texas and Roumanian oils, comparing oils always of identical viscosity at 50° C.

In similar relationship appears to be the constant for carbon residue (column 8). It is revealed with this standardized coking-procedure, the more volatile oils—therefore, those in general with the heavier (higher) specific gravity—all show lower Conradson carbon values, as seen in Table 1. Only oils which were refined to the same degree are compared.

As to oxidation characteristics (sludge-formation) it can be said that the lightest specific gravity Pennsylvania oils appear to be the most resistant, and that sludge formation increases approximately with increase in specific gravity—that is, with increases in the asphaltic and naphthenic character of the oil.

It must be remembered, however, that the chemical composition of an oil as indicated by specific gravity is not the only underlying cause or prime reason which gives rise to certain definite values for the C. C. residue, percent sludge-formation, and other similar tests. Such tests are also influenced quite often by the presence of asphaltic substances, sulphur compounds and chemical groups containing oxygen in their structure, which may well act as catalysts to induce oxidation and again may act, in other cases, as true oxidation inhibitors. Here again one must cautiously interpret results when additives have been added to an oil, such as anti-oxidants. This practice has been employed for years in the automotive fuel industry.

Granted that the specific gravity is characteristic of many of the properties of oils of equal viscosity, it is clear that oil blends will also behave or give relatively identical results of physical-chemical tests—assuming such mixtures are compared with oils of equal viscosities and which are grouped and classified as to their own viscosity and specific gravity. And this independent of the fact that the mixtures may be composed of oils and cuts of widely different origin and chemical nature, or even of close boiling-range cuts and residue oils. This assumption appears substantiated in the values shown in Table 2. The oils contain no additives, and the results bear out the assumption at least, one may say, for the properties of viscosity at elevated temperatures.

Group (a) in Table 2 shows a Russian oil and also a mixture of Roumanian and "straight- run" lube oil; group (b) a Mid- Continent oil, and for comparison a mixture of Russian and Pennsylvania oils. Group (c) a special narrow-boiling-point-range Balachany oil, and a mixture of light Roumanian oil with a United States bright stock; group (d) a refined and an unrefined similar origin Roumanian oil.

It is seen that the viscosity curves and partly the constants derived from them are practically identical. The agreement in the absolute viscosity at 200° C. is especially noteworthy. It is not to be expected that such exact agreement can also be obtained in the case of the C. carbon values or the values for oxidation resistance, as was already partly explained previously; this is especially true for group (d) where we present two oils which are very different in the content of "hard asphalt."

All in all, the relationships, uniformity and agreement between specific gravity, the boiling-point characteristics, and the temperature-viscosity curves are quite apparent for all unadulterated oils. This uniformity or trend in some one direction has been mentioned by other investigators[6], though described in rather brief fashion. These united properties are, of course, entirely dependent on the average properties of the various series of hydrocarbons which constitute the lubricating oil; the same applies for any single group of pure hydrocarbons which may compose a narrow-boiling-point cut of lubricant. It is therefore clear, and must follow quite conclusively, that the determined constants, evaluated as carefully as possible, are indicative of the nature of the hydro-

TABLE 2

GROUP	Sample	ORIGIN OF SAMPLE	Viscos. 50 °C. °E.	Spec. Grav. 20 C.	Pour Point	Absol. Visces. Centipoises at 30	500	100	200	Sp. Gr. Visc. Const.	V. I.	Con. Carbon Percent	Oxidation Test Percent Sludge
			1	2	3	4				5	6	7	8
A	C-35	Grosny	4.19	0.902	+8	75.3	27.5	5.51	1.72 (170°C.)	0.851	32	0.11	7.5
	C-36	Mix of 47% Roum. (4.6 °E., 0.932)+ 53% Penn. (4.1 °E. 0.875)	4.22	0.902	−6	75.8	27.2	5.56	1.69	0.851	32	0.23	6.8
B	S-51	Mid-Cont.	22.85	0.914	−5	539	140.	16.95	2.15	0.844	59	1.05	....
	D-2	Mix. of 56% Russ. (22.6 °E., 0.935)+44% Penn. (22.7 °E 0.886)	22.16	0.915	−4	595.8	147.6	16.84	2.25	0.844	50	1.20	....
C	D-4	Close Cut Balachany	10.9	0.931	−2	317.4	73.8	9.7	1.60	0.876	5 7	0.20	....
	P-6	Mix. of 72% Roum. (6.7 °E. 0.934)+28% Br. Stock (57. °E., 0.910)	11.06	0.931	−19	310	73.8	10.2	1.60	0.876	20	0.66	....
D	P-4	Ref'd Rouman	22.53	0.947	−11	780	158.5	14.65	1.85	0.890	22	0.43	....
	P-5	Untreated Roumanian	22.31	0.947	+10	971.1	158.8	14.09	1.87	0.890	8	1.45	....

TABLE 3

Group	Sample No.	Visc. 50 C. °E.	Spec. Grav. 20 C.	ANALINE POINT Before Removal of Aromatics	ANALINE POINT After Removal of Aromatics	Dispersion	Aromatic Hydrocarbons Percent	Apparent Mol. Wt.	ELEMENTARY ANALYSIS PERCENT C	H	S	Ash	CALCULATED ON PURE CH-HYDROCARBON Elementary Composition Percent C	H	Apparent Formula	Apparent General Series
		1	2	3			4	5	6				7		8	9
A	C-34	4.08	0.875	104.9	111.0	6.1	16.8	338	86.34	13.31	0.11	0.0	86.64	12.36	$C_{31.6}H_{58.5}$	$C_nH_{2n-4.7}$
	C-35	4.19	0.902	91.1	104.8	13.7	33.7	399	87.26	12.48	0.17	0.07	87.49	12.51	$C_{29.1}H_{49.0}$	$C_nH_{2n-8.3}$
	C-33	4.56	0.932	71.0	93.3	22.3	48.4	369	87.33	12.05	0.27	0.11	87.87	12.13	$C_{27}H_{41.8}$	$C_nH_{2n-9.2}$
B	S-29	11.15	0.881	120.3	124.9	4.6	12.9	609	86.63	13.26	0.09	0.03	86.73	13.27	$C_{44}H_{90.8}$	$C_nH_{2n-7.2}$
	S-111	11.46	0.890	114.0	120.7	6.7	18.2	517	86.77	13.04	0.09	0.06	86.94	13.06	$C_{37.4}H_{67.5}$	$C_nH_{2n-7.3}$
	S-32	11.32	0.902	103.8	115.5	11.7	30.0	494	86.94	12.7	0.23	0.10	87.25	12.75	$C_{35.9}H_{63.0}$	$C_nH_{2n-8.8}$
	D-4	10.9	0.931	84.3	99.4	15.1	36.4	413	87.44	12.23	0.26	0.07	87.73	12.27	$C_{30.2}H_{50.7}$	$C_nH_{2n-9.7}$
	S-20	10.96	0.938	78.6	101.0	22.4	48.6	395	86.90	11.96	0.21	0.02	87.90	12.10	$C_{28.9}H_{47.9}$	$C_nH_{2n-9.0}$
C	S-28	22.65	0.886	126.2	136	9.8	26.6	738	86.50	13.38	0.05	0.0	86.60	13.4	$C_{53.2}H_{98.8}$	$C_nH_{2n-7.6}$
	S-100	22.9	0.888	125.4	133.5	8.1	22.0	722	86.56	13.53	0.04	0.06	86.48	13.52	$C_{52}H_{97.6}$	$C_nH_{2n-6.4}$
	S-62	22.6	0.892	125.2	133.0	7.8	21.5	649	86.78	13.29	0.05	0.04	86.72	13.28	$C_{46.9}H_{86.1}$	$C_nH_{2n-7.7}$
	S-5	22.08	0.910	109.1	120.2	11.1	28.7	553	86.88	12.77	0.32	....	87.19	12.81	$C_{40.2}H_{70.8}$	$C_nH_{2n-9.4}$
	S-96	21.9	0.913	106.7	118.4	11.7	29.8	531	87.14	12.90	0.22	....	87.11	12.89	$C_{39.6}H_{68.4}$	$C_nH_{2n-8.8}$
	S-51	22.85	0.914	105.4	117.1	11.7	29.8	519	87.15	12.72	0.23	....	87.26	12.74	$C_{37.7}H_{66.2}$	$C_nH_{2n-9.2}$
	S-115	22.44	0.934	92.8	110.6	17.8	41.3	460	87.40	12.21	0.34	....	87.74	12.26	$C_{33.6}H_{56.4}$	$C_nH_{2n-10.8}$
	S-40	22.60	0.935	87.8	107	19.2	44.2	451	87.26	12.23	0.31	....	87.71	12.29	$C_{33}H_{55.4}$	$C_nH_{2n-10.6}$
	P-4	22.53	0.947	76.6	102.6	26.4	54.6	432	87.29	12.06	0.22	0.47	87.87	12.13	$C_{31.6}H_{52.4}$	$C_nH_{2n-10.8}$

carbon (or its series) itself, and which must also reveal regularities in conjunction with the specific-gravity determination.

We therefore next undertook chemical analyses of the oil samples described so far in order to substantiate the statements made above. The pertinent results that were obtained are shown in Table 3 and 4.

Table 3 is a continuation of Table 1 and comprises the same group of oils of similar viscosity. Table 4 is a continuation of Table 2 comparing oils of similar viscosity and specific gravity.

The content of aromatic hydrocarbons (column 4) was determined by the method and coefficients of Sachanen and Wirabianz[7]. The aniline point before and after sulphuric acid treatment (column 3) was determined by the depression in pure aniline; the latter constants are those for a mixture of 1:1 of oil and aniline. Apparent molecular weights (column 5) were determined by the procedure of Epperson and Dunlop[8], being a freezing-point depression method using c.p. benzole. In Table 3 and 4 are also given the multimate analyses (column 6), and are recalculated for the pure hydrocarbon on the basis of Ch-substance in column 7.

From the molecular weight and ultimate analysis we next calculated the apparent formula (column 8), and the apparent general formula or series is shown in column 9.

It is seen that the content of hydrocarbons containing aromatic rings (column 4, Table 3) increases consistently with increasing specific gravity, comparing oils of similar viscosity at 50° C. Reversely, (and as one would expect) the hydrogen content of the oil samples (column 7) decreases in parallel fashion. It is noteworthy also to see that the aniline point of the oils freed of aromatic hydrocarbons (column 3) steadily decreases—an indication of the fact that with increasing specific gravity not only do aromatics but also the naphthenes prevail over and above the so-called "paraffinic" lubricant hydrocarbons.

The molecular weights (column 5) appear unexpectedly to be affected by the presence of mixtures of so-called paraffinic and naphthenic hydrocarbons. With decreasing specific gravity one notes a very definite increase in molecular weight. This is in relation to the corresponding higher average boiling-point. For instance, in column 8 an oil is shown composed of an average molecular constitution of 32 carbon atoms at 4 E. viscosity with a specific gravity of 0.875; again, another oil contains hydrocarbons whose molecules contain only 27 C atoms—of 0.932 specific gravity, at 22° E. viscosity. An oil showing 0.886 specific gravity will analyze 53 C atoms while an oil of 0.947 gravity shows only 32 atoms of carbon.

The above observations are especially substantiated by the fact that one will find good agreement in the literature for these hydrocarbon series. This is especially true as regards the lower members of such series. Many of the hydrocarbon series are now well classified in recent literature.

Some interesting results are further obtained from the calculated general formula in column 9. We will allude briefly to them here, as the facts are already well known. For instance, it is known that the so-called "paraffinic" oils can scarcely be composed of

TABLE 4

Group	Sample No.	Visc. at 50 C.	Spec. Grav. 20 C.	ANALINE POINT Before Removal of Aromatics	ANALINE POINT After Removal of Aromatics	Dispersion	Aromatic Hydrocarbons Percent	Apparent Mol. Wt.	ELEMENTARY ANALYSIS PERCENT C	H	S	Ash	CALCULATED ON PURE CH-HYDROCARBON Elementary Composition Percent C	H	Apparent Formula	Apparent General Series
		1	2	3			4	5	6				7		8	9
A	C-35	4.19	0.902	91.1	104.8	13.7	33.7	399	87.26	12.48	0.17	0.07	87.49	12.51	$C_{29.1}H_{49.0}$	$C_nH_{2n-8.3}$
	C-36	4.22	0.902	89.3	102.2	12.9	32.0	405	87.18	12.56	0.19	0.02	87.41	12.59	$C_{29.5}H_{51.0}$	$C_nH_{2n-8.0}$
C	D-4	10.90	0.931	84.3	99.4	15.1	36.4	413	87.44	12.23	0.26	0.07	87.73	12.27	$C_{30.2}H_{50.7}$	$C_nH_{2n-9.7}$
	P-6	11.06	0.931	87.2	104.2	17.0	39.8	405	87.45	12.27	0.30	0.06	87.78	12.22	$C_{29.6}H_{49.5}$	$C_nH_{2n-9.7}$
D	P-4	22.53	0.947	76.6	102.6	26.4	54.6	432	87.29	12.06	0.22	0.39	87.87	12.13	$C_{31.6}H_{52.4}$	$C_nH_{2n-10.8}$
	P-5	22.31	0.947	79.8	106.7	26.9	55.7	454	87.48	11.96	0.41	0.10	87.98	12.02	$C_{33.3}H_{54.6}$	$C_nH_{2n-12.0}$

true paraffins; oil "c-34," a light pure Pennsylvania oil of only 16.8 percent aromatic content calculated to belong to the series C_nH_{2n-4}, a series which indicates three-ring polynaphthenes. From the array of data presented other calculations again indicate that, with an increasing content of "naphthenic character" of these oils (therefore increasing specific gravity), the number of side chains on the polynaphthene ring-system appears to diminish consistently. Finally, in the case of the purely aromatic oils there is a great preponderance of chainless rings, both aromatic and naphthenic.

From our investigations one can say at this point that the oils in Table 4 are similarly constituted as to hydrocarbon series, after grouping them as to viscosity and identical specific gravity. The content of aromatics, the molecular weights, the ultimate analyses, and the apparent formulas of the oils grouped for comparison are further reasons for pointing out the similarity in composition. The errors seen in analyses are practical laboratory errors.

In conclusion it can be said that petroleum lubricants which are well refined have been grouped together as to their similar viscosity at 50° C. and these oils have been compared. It appears that the specific gravity is a characteristic of the average chemical composition of lubricant oils and for all such other physico-chemical properties that are dependent on constitution.

With an increase in the specific gravity the average boiling-point, the molecular weight, the aniline point, as well as the hydrogen content appears to decrease in regular fashion. In accordance with these facts we find the viscosity-temperature curve to become steeper and the c. carbon value appears to decrease. With a further increase in aromatics and naphthene the lower resistance toward sludge-formation (evident throughout with increase in aromatics) finally becomes very pronounced.

Certain of these properties can, however, be affected by many factors. These factors are the degree and type of refining, the presence of coloring matter or asphalts, the nature of the latter, and again by the presence of modern lubricant additives. The latter can act either as pro-oxidant or anti-oxidant substances, and also affect the molecular weight and the carbon-hydrogen ratio (ultimate analyses). Care should be exercised to determine the origin of the oil and the degree and manner of refining.

BIBLIOGRAPHY

[1] Standard Methods (Vi Edition 1933) p. 98.
[2] J. Indust. Eng. Chem. 20, 641 (1928) and Anal. Ed. 3, 144 (1931).
[3] Chem. & Met. Eng., 36, 618 (1929); SAE Journ., 29, 247 (1931); Oil & Gas Journ., 30, NR. 46, 93 (1932).
[4] ASTM Standards on Petroleum Products (1934-Aufl.), S. 49.
[5] Petroleum 29, Nr. 40, 1-14; Nr. 41, 1-13 (1933).
[6] Blackwood & Rickless: SAE Journ., 28, 136 (1931); Mougey: SAE Journ., 29, 200 (1931); Ehlers: Petroleum, 28, Nr. 41, 8 (1932); McCluer & Fenske: Ind. Eng. Chem., 24, 1371 (1932); Larson & Schwaderer: Nat. Pet. News, 25, Nr. 9, 25-28 (1933).
[7] Erdol & Teer, 9, 170-172, 187-189, 202-203, 220-222 (1933).
[8] Ind. Eng. Chem., 24, 1369 (1932).

Calculation of Minimum Ratio for Multicomponent Distillation

A CORRECTION

An error in Figure 5 of the paper "Calculation of Minimum Reflux Ratio for Multicomponent Distillation," PETROLEUM REFINER, Vol. 25, No. 4, page 141 (April, 1946), has been corrected by a communication from the authors as follows:

Figure 5 should appear as shown herewith; and the first paragraph on page 148, which is the second paragraph of the section entitled "Typical Phase Diagrams," should be changed to read as follows:

A typical y-x diagram for component d (the heavy key) is given in Figure 5 for d with c only and for d present in the (--- + a,b,c/d) mixture in a column operating at minimum reflux. Note that for the condition of minimum reflux there is a "pinch" section of infinite plates in the lower part of the column where the concentrations of all components lighter than the light key are essentially zero. With only the two key components (c and d) present the y-x curve for component d in the multicomponent column operating at minimum reflux coincides with the y-x equilibrium curve for the (c,d) mixture; these two curves coincide from the "pinch" point, the composition of which is $d'/(c + d')$ as specified above for the (c,d') binary, on up to $X_d = Y_d = 1.0$.

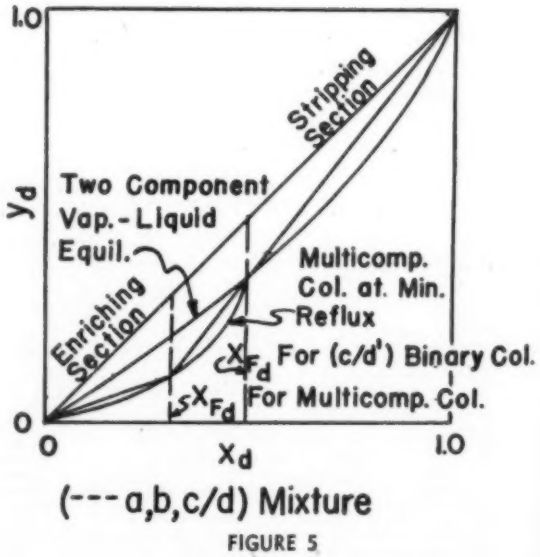
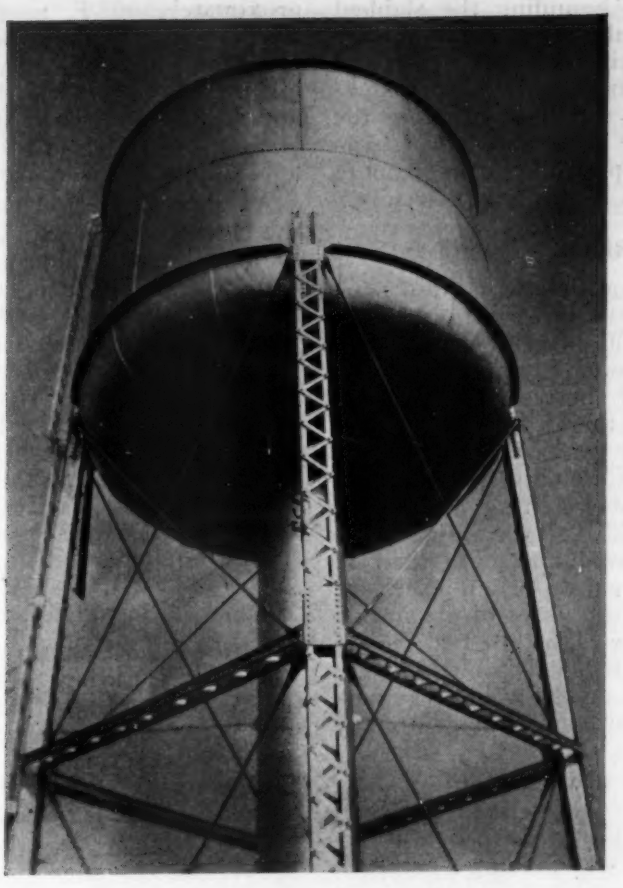


FIGURE 5



Method Of Reconditioning Elevated Water Tanks

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FOLLOWING an increasing amount of internal corrosion on the bottom and sides of several elevated steel water tanks, a large gas utility organization worked out a systematic procedure for inspecting, repairing, coating and applying cathodic protection to the working tanks at several of its main line compressor stations.

The 50,000-gallon tanks are used to store engine-jacket-cooling water. In normal operation they are connected in the discharge line of the water-circulating pumps and "float" on the delivery line leading to the main engine. They serve the dual purpose of providing adequate capacity storage for cooling water and also of providing an emergency supply of cooling water in case the circulating water pumps should be out of service for a short period. In the latter case cooling water can gravity over the engines while repairs are being made to the pumping units.

The tank proper is of riveted construction with the sides and bottom 5/16-inch thick. During a year's operation a considerable amount of scale and sediment settled over the bottom of the tanks. This precipitation stimulated corrosion, with the result that the tank bottoms were generally pitted and eventually developed leaks in scattered locations, either from actual penetration of the bottom steel plates or as the result of a rivet being weakened by corrosion to the extent that leakage developed around the rivet or in the seam being held by the rivet.

To make the proper repairs it was necessary to drain the tank and wash down the excess sedimentation by means of a small fire hose, using approximately 45 psi water pressure. This amount of pressure was adequate to effect a fairly good job of cleaning on the tank interior. After the tank had dried thoroughly the interior was carefully inspected for deep pits, "slab" corrosion and weakened rivets. The bottom is comprised of 19 segments, and for reference purposes, each segment was assigned a number.

Beginning the inspection on say, Section 1, the three most important types of corrosion failures to note were (1) pits having a depth exceeding 150 mils, (2) "slabbed" areas, and (3) rivets that had become loose as a result of corrosion.

The deep pits were circled with a chalk mark for subsequent welding; the slabbed areas were bounded with chalk marks to determine patching requirements, and the weakened rivets were marked for

electric welding. The marks bounding the slabbed areas were measured and tabulated for use in cutting out the required patches. Incidentally, it was found that ⅛-inch steel plate was more suitable for patching the tank bottom due to the ease in fitting the patch to the curvature of the bottom sheets. It was only necessary to tack the patch on one or more sides and then hammer it to shape before welding.

Weakened Rivets

The extent of rivet deterioration was often such that on slight movement of the rivet it would drop out of place. The method of electric welding the weakened rivets in such a manner as to prevent seam buckling on adjacent sides of the welding operation and yet stop all leakage is therefore of particular interest. This was performed in the following manner: The 200-ampere electric welding machine was adjusted to its lowest possible setting and, using 5/32-inch rod, a rivet was welded all the way around. This operation usually required not more than 12 seconds, which was insufficient to attain excessive heating of the steel plate. As a matter of precaution no other welding was performed within two feet of a completed rivet until that rivet had cooled. By exercising the same precautions on the welding of tank seams, repairs were made without damage to any portion of the water tank.

As an illustration of the small amount of heat evolved in the welding process described above, it was possible to hold the hand on a rivet just 30 seconds after the conclusion of the welding operation.

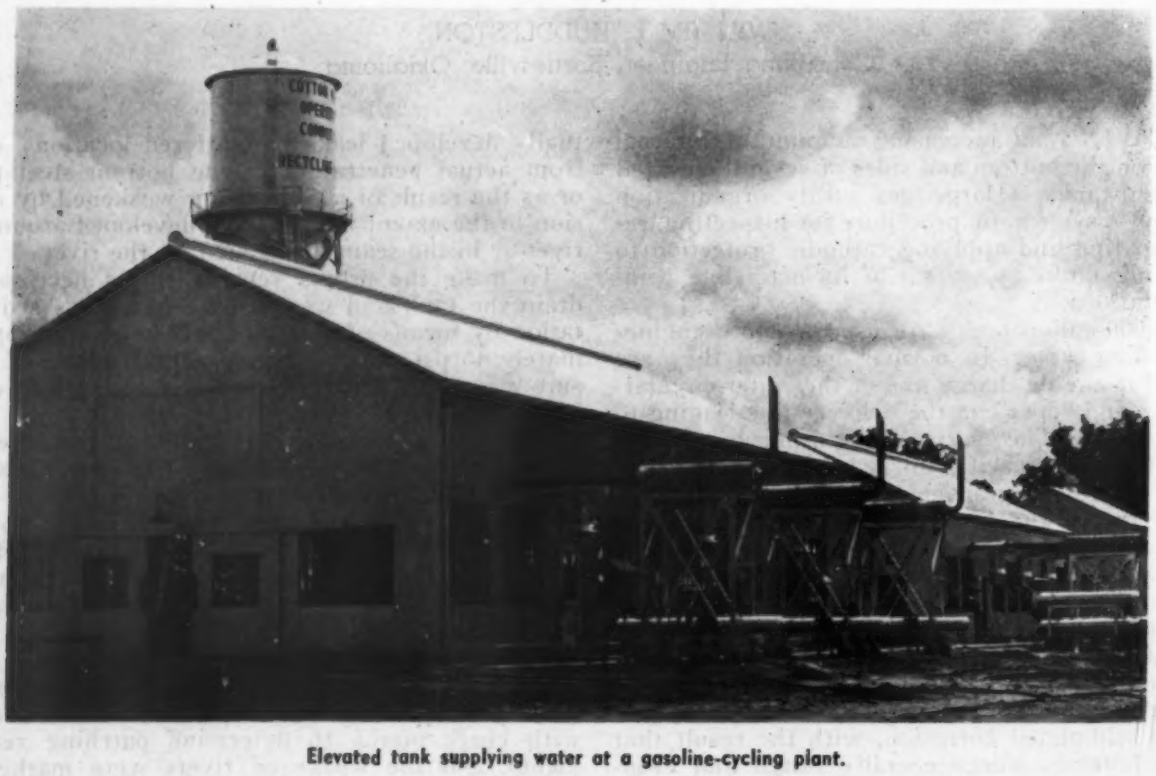
After completing the necessary repairs the tank and cylinder interiors were coated with a single application of a coal tar service cement preparatory to installing cathodic protection. For best results the following precautions should be observed during the coating procedure: The tank wall should be clean and dry. Although the protective cement is for a cold application, preheating to a temperature of approximately 90° F. in times of cold weather will facilitate easier application. Better results can be obtained if the coating operation is not performed during extremely cold weather. The coating will harden appreciably and result in a better job if the tank is left out of service for at least 10 days following the application of the coating.

As a means of preventing further deterioration of the elevated water tanks it was considered advisable to install cathodic protection to each tank immediately after the necessary repairs had been completed. Accordingly, an 8-volt, 8-ampere cathodic rectifier was connected and adjusted to facilitate the proper amount of protection. A study of water samples from several of the tanks resulted in standardization of the capacity described above. Pipe anodes were used on all tanks and the spacing of the individual anodes within the various tanks was modified in certain cases in order to establish the most favorable load resistance for efficient operation of the rectifying equipment.

Economics of Reconditioning

At the time leaks first developed on the elevated water tanks, reconditioning was considered the most feasible method of dealing with the corrosion problem, partly because of the slow (and perhaps indefinite) delivery of steel and other needed materials and partly because of the savings that could be effected through the reconditioning procedure.

Cost of replacing a tank bottom was estimated at $4,800 and the time required to make the replacement was estimated as being several months. The average cost of reconditioning, coating and installing a cathodic protective unit on each tank amounted to approximately $950, or slightly less than 20 percent of the replacement cost. These figures pertain only to the tanks in the greatest need of repairs, and in which cases an outright tank bottom replacement normally would have been recommended.



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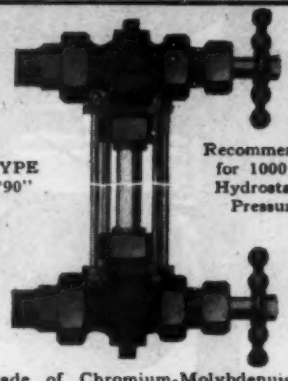

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Used to observe color and density of liquids under high pressures and/or temperatures. Construction exceptionally sturdy. Made of alloy temperature resisting steel, and are highest quality throughout. Liquid chamber made from solid block of steel to assure perfect alignment and rigidity. Conform with A.P.I.—A.S.M.E. requirements.

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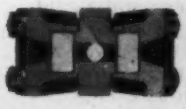


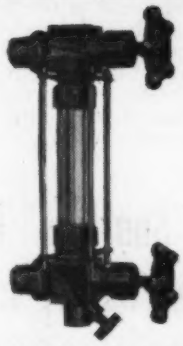
PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

"ALL IRON"

LIQUID LEVEL GAGES



Body made from a special high strength alloy iron, shanks alloy steel and trim stainless steel. Extra heavy construction throughout, automatic and positive shut-off if glass breaks, heavy duty stuffing boxes. Conform with A.P.I.—A.S.M.E. requirements.

The "All Iron" is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

QUALITY PRODUCTS

Penberthy injectors—ejectors—automatic electric and water (or steam) operated sump pumps are all widely used throughout the oil industry because they have always been dependable under the most severe service conditions.

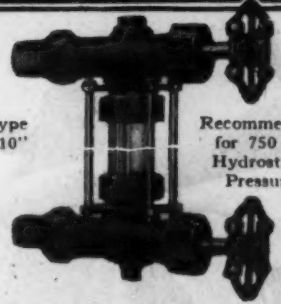
All are of rugged construction and made by an organization with 59 years experience in the manufacture of highest quality products.

PENBERTHY INJECTOR CO.

DETROIT 2, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

DROP FORGED STEEL LIQUID LEVEL GAGES



Type "10"

Recommended for 750 lb. Hydrostatic Pressure

Steel construction throughout with stainless steel interior trim. Automatic shut-off is positive and instantaneous; stainless steel balls shut off the flow of liquid when glass breaks. Heavy duty stuffing boxes, union connections, offset construction facilitate cleaning and simplify glass replacement. Conform with A.P.I.—A.S.M.E. requirements.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.

DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

OPERATION HOW TO DO IT MAINTENANCE

Compressed Air Storage Made From 16-Inch Pipe

COMPRESSED air storage requirements were safely and economically solved by the operators in an East Texas gasoline plant by construction of the storage drums shown in the photograph. Air under pressure of 250 psig is available for starting compressors and other uses about the plant at all times. The volume of the drums has proven sufficient for all purposes to date.

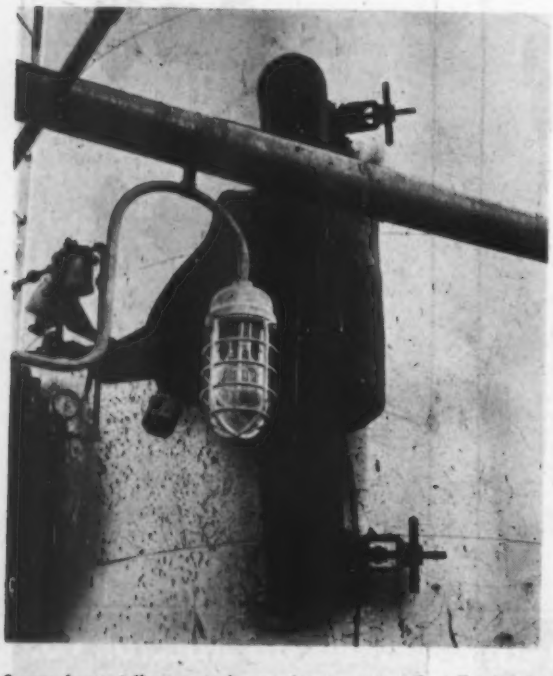
The three "drums" were made of 40-foot lengths of 16-inch well casing. The ends of each drum were cut and welded into rounded heads, and nine 12-inch long braces of 4-inch pipe were cut and welded into the three lengths of casing to serve as spacers and to interconnect each drum. The drums were placed on pipe racks about a foot off the ground, and given a coating of aluminum paint for rust prevention. Compressed air enters the lower left drum and is withdrawn from the other end of the lower right drum. A connection to supply air to the laboratory is shown in the center of the third and top drum.

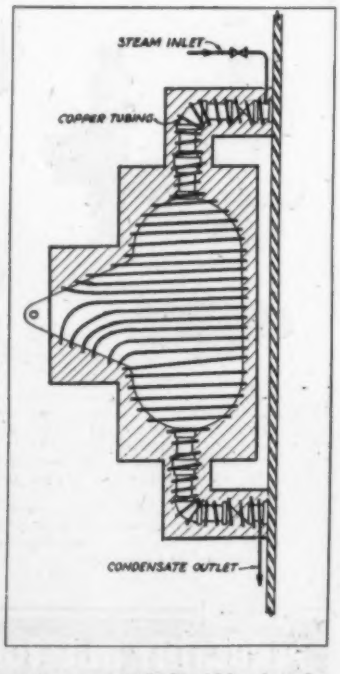
Three 40-foot lengths of 16-inch pipe provide storage for sufficient 250-pound air for plant needs.

Liquid-Level-Float Cage For Viscous Materials

EXTERNAL type float cages for liquid-level controllers have certain advantages in convenience and accessability, but where they are used in services involving heavy viscous materials such as asphalts they are prone to "freeze-up" because of loss of heat by radiation to atmosphere.

One asphalt plant superintendent has devised a means for heating this type of level controller to keep it in satisfactory operation. As indicated on the photograph and diagram, the float cage is wrapped with ¼-inch copper tubing spaced at about 1-inch centers, held in place with a layer of chicken wire, well insulated against heat loss by a heavy covering of magnesia block insulation, and weatherproofed by a coating of emulsified asphalt. Steam is admitted into the tubing coil at the top, and condenses, maintaining sufficient temperature to keep asphalt from solidifying in the float cage. Steam condensate drains out at the lower end of the coil, either through a hand valve or through a steam trap, as desired.





Steam-heated float cage keeps viscous material at flowing temperature so outside liquid level works.

Steam "Snuffers" for Fires On Tower Safety Valves

THE operators of a gasoline plant in an area where frequent electrical storms occurred were troubled by lightning striking the safety valves on the various towers—causing leaks and igniting the escaping gas. It was necessary for an operator to climb the tower and put the fire out with a steam hose, an unpleasant task in stormy weather.

To reduce the hazard of putting out the fire, the operators used ⅜-inch pipe to conduct steam to the top of the tower through a tee and two short pipe nipples to the discharge lines of the safety valves. A ¼-inch hole drilled in the dis-

Preferred for catalytic cracking plants

Catalyst regeneration in catalytic cracking processes calls for a continuous unfailing supply of air. Many of the "cat cracker" plants get this critically important air supply from Elliott centrifugal blowers.

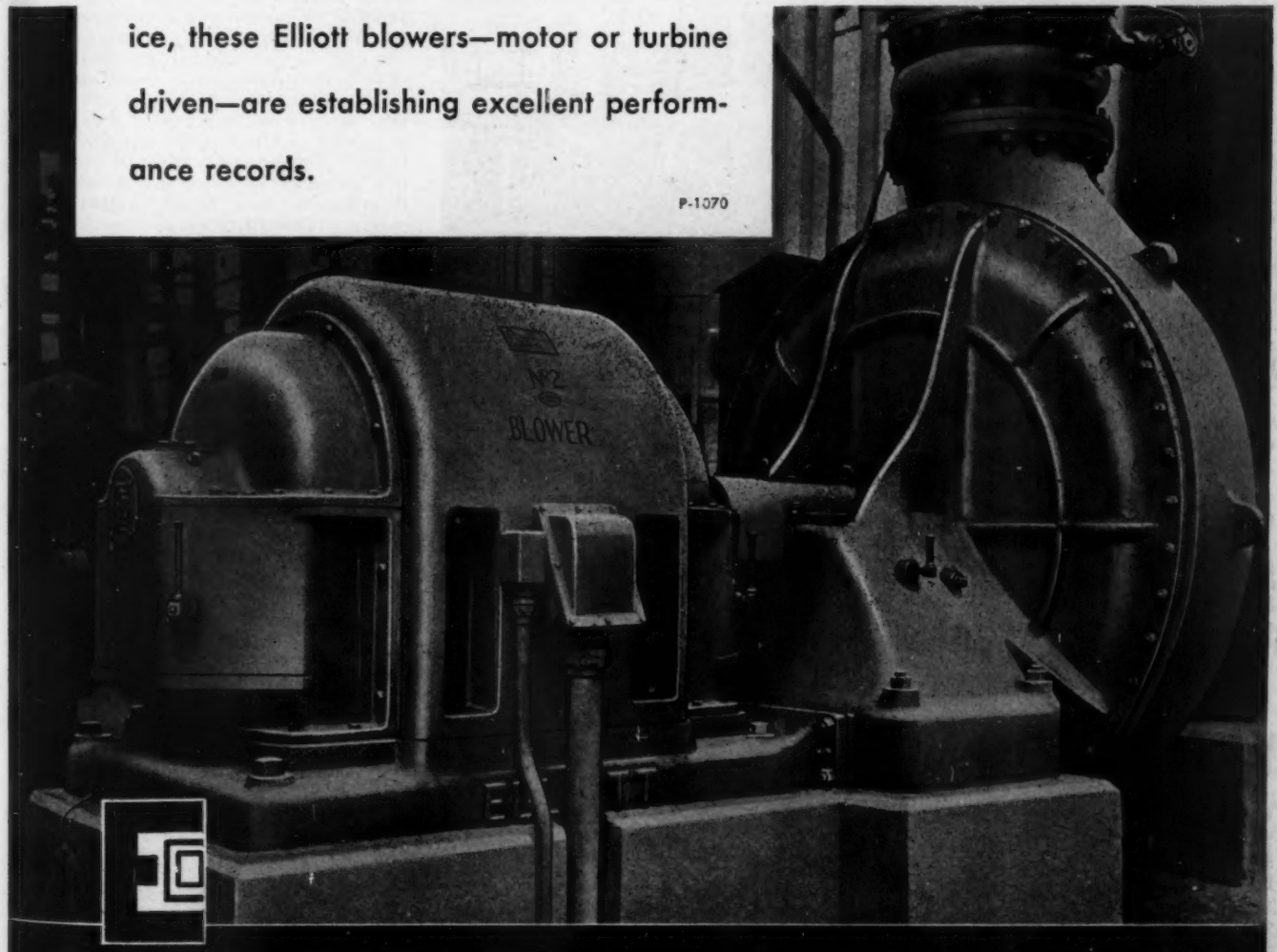
Carefully designed and built for the service, these Elliott blowers—motor or turbine driven—are establishing excellent performance records.

P-1070

ELLIOTT BLOWERS

A COMPLETE BLOWER UNIT

Elliott 21,500-cfm blower (one of three duplicate units in this plant), driven by 350-hp Elliott high-speed, 3550-rpm motor, supplies air at 2.5 psiG pressure for catalyst regeneration in the Thermofor Catalytic Cracking unit at the 10-7 plant of the Sun Oil Company in Marcus Hook, Pa. Both motor and blower are designed for outdoor operation.



ELLIOTT COMPANY

Centrifugal Blower Dept., JEANNETTE, PA.
Plants at: JEANNETTE, PA. • RIDGWAY, PA.
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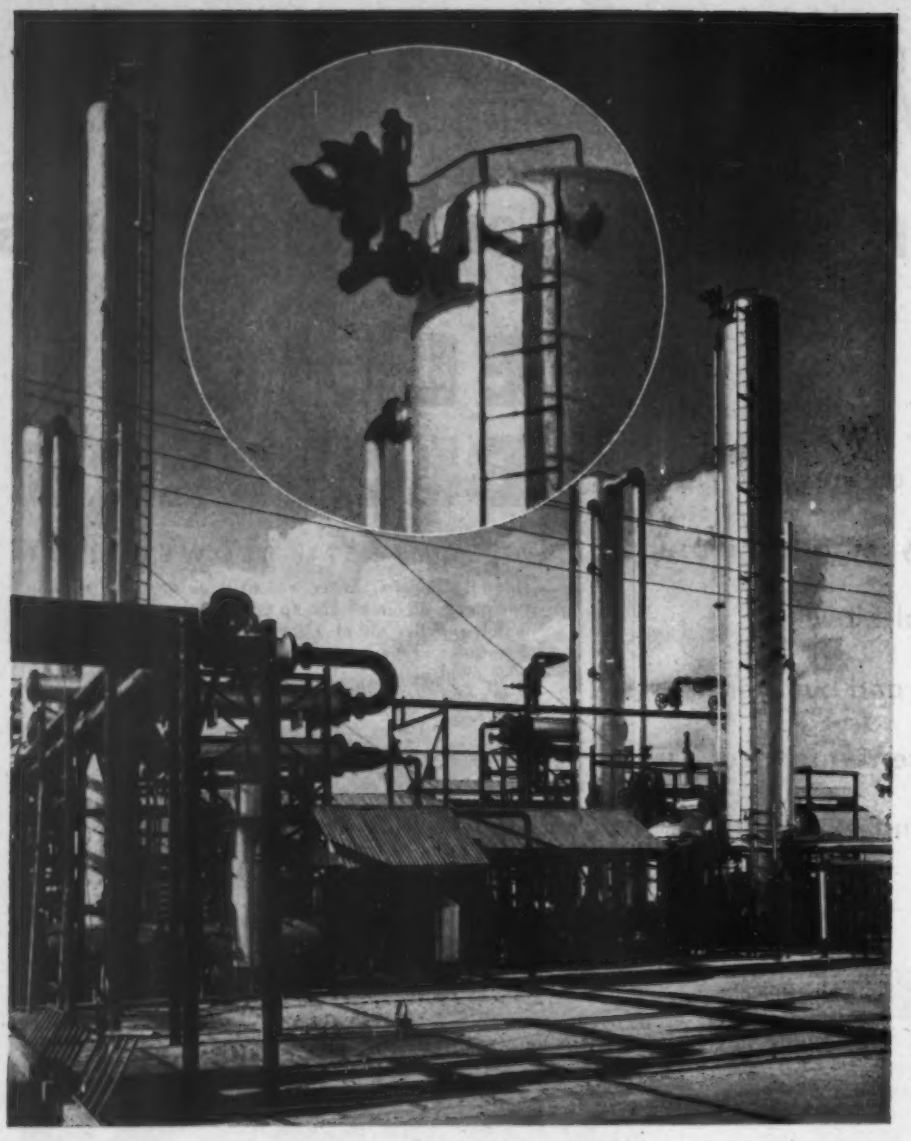
DISTRICT OFFICES IN PRINCIPAL CITIES



When lightning ignites gas from safety valves on towers, a steam connection extinguishes it.

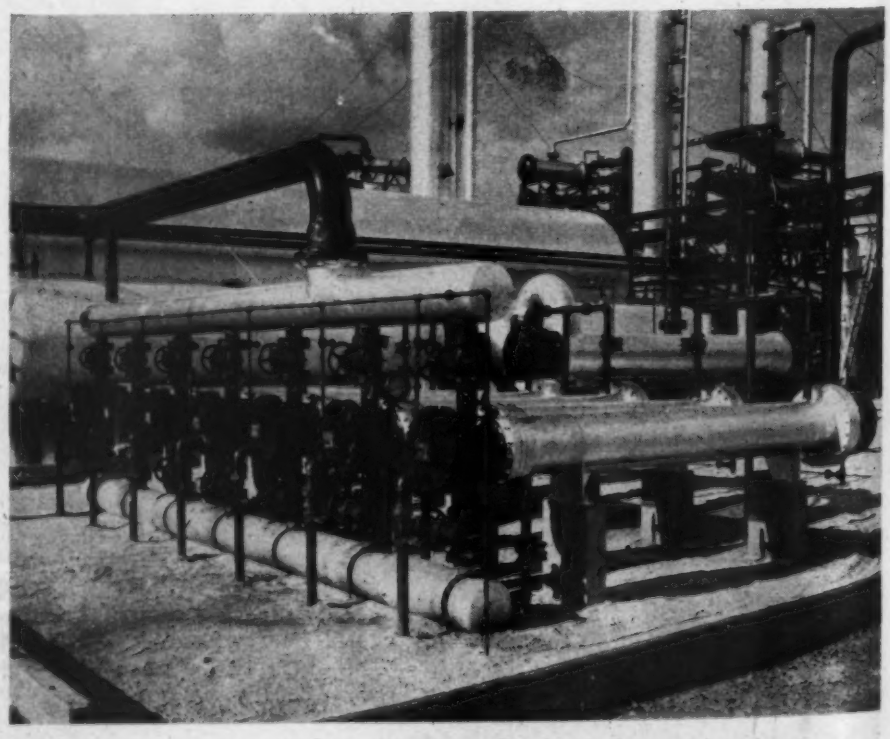
charge line permits steam condensate to drain from the line.

When the valves are struck and the leaking gas ignited, the operator opens a valve in the ¾-inch line and permits steam to snuff out the blaze. This system was installed on all towers in the plant. Fires are put out and quicker and safer by this method.

Manifolding Exchangers Simplifies Operation

RECENT replacement of the gasoline heat exchangers in a gasoline plant permitted the operators to install the manifolded system as shown in the accompanying photograph, which has resulted in simplified operation and maintenance. Each exchanger is mounted on a concrete base with a manifold line above and below the head end of the exchanger. Flanged valves and welded pipe nipples are used to connect the exchanger to the manifold lines. Other connections are made with screw pipe having a union joint in the pipe near the exchanger. Welded flanges are used in the shell connections.

The manifold system permits operation of as many exchangers as is needed and they are readily accessible. When a leak occurs, or when an exchanger must be taken out of service for retubing, the valves are closed and the flanges and union joints disconnected at the valves on the exchanger side, the head bolts are removed and the tube bundle of the exchanger easily removed.



Manifolded heat exchangers in natural gasoline plant result in simplified operation and maintenance.

"Snifter" Valve Keeps Pump Air Chamber Filled

AIR volume in cushion chambers of reciprocating pumps commonly is assumed to be adequate, and little attention is given to loss of air through leaks or absorption. This loss eventually results in the chamber being filled with fluid, and the air chamber loses its effectiveness in preventing hammer in the lines. To replace the lost air it is necessary to remove the chamber, empty the fluid and replace the unit on the pump, all of which takes time. In some instances the practice is to connect a compressed air line to the top of the chamber so that air can be introduced to restore the chamber to its original condition.

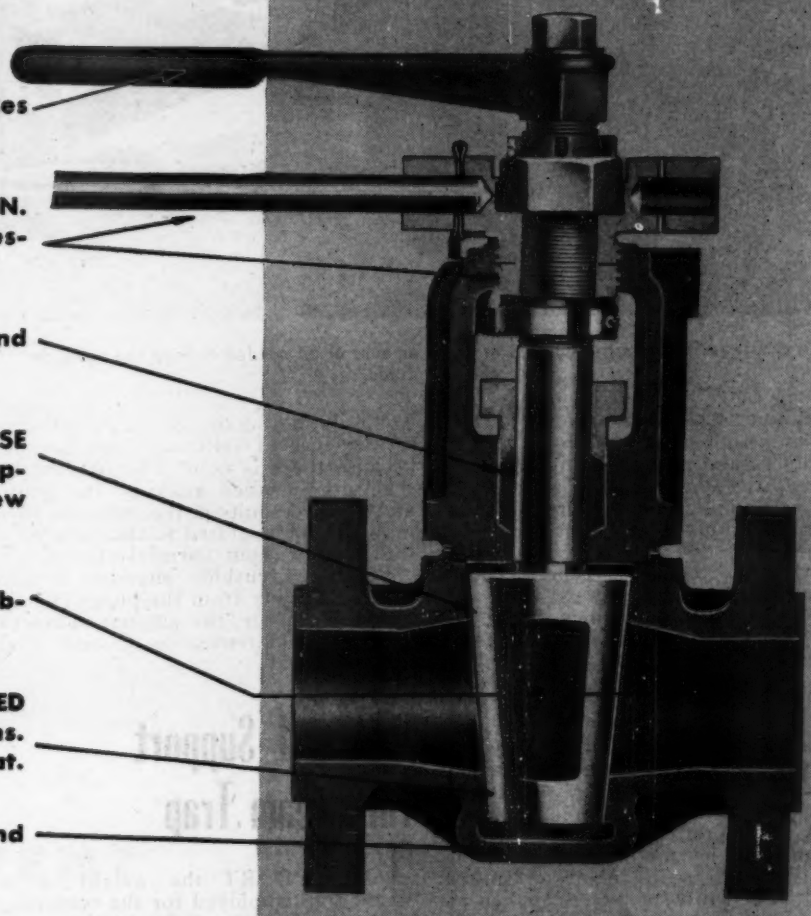
Automatic introduction of air into the cushion chambers recently was applied to pumps of Union Oil Company of California. Before application of this method, air was supplied by venting and draining the fluid. Later, compressed air was supplied through a system of pipe lines or from a portable compressor, but proved unsatisfactory because of lack of facility for determining how much air was in the chamber and when to replenish the supply.

This company operates a number of reciprocating pumps with as many as three in multiple in an emulsion-breaking unit, which consistently developed pipe

Homestead Lever-Seald Valves

Proved for over 15 Years

in Services from 40° below zero to 1120° Fahrenheit



A QUARTER-TURN fully opens or closes valve.

INSTANT STICKPROOF OPERATION. Plug turns freely after seating pressure is relieved by screw lever.

LEAK PROOF. Deep stuffing box and gland prevent leakage.

POSITIVE LEAKLESS SEAL WITHOUT USE OF LUBRICANT is obtained by reapplying full seating pressure with screw lever after opening or closing.

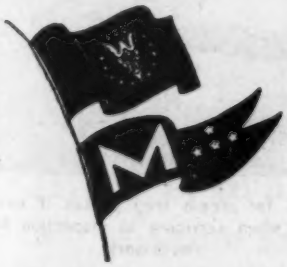
STRAIGHT-LINE FLUID FLOW. No obstructions to cause pressure drop.

SEATING SURFACES ALWAYS PROTECTED in both open and closed positions. Fluid or grit cannot damage valve seat.

SEALED BOTTOM prevents fluid loss and reduces hazards.

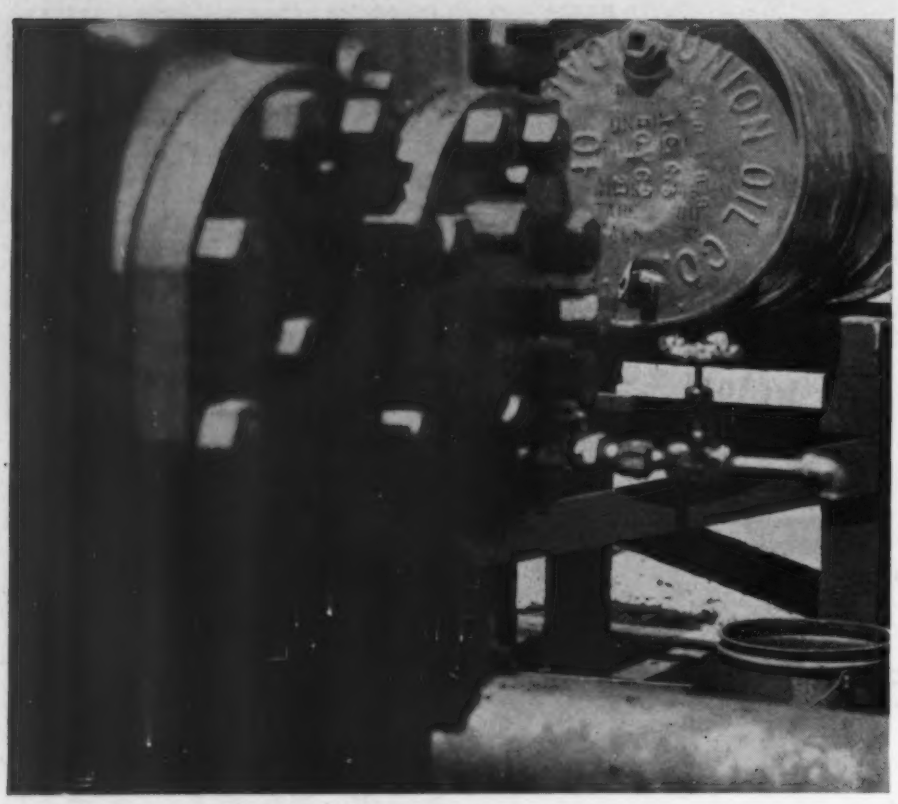
For more than 15 years America's leading chemical plants, oil refineries, paper manufacturers, textile mills and steel companies have been using HOMESTEAD LEVER-SEALD VALVES to solve their operating difficulties in services where temperature extremes, pressures, and the corrosive action of line fluids would make ordinary valves stick or seize. Due to their exclusive lever-seald construction, HOMESTEAD LEVER-SEALD VALVES operate freely and effectively at temperatures as low as 40° below zero or as high as 1120°.

Consult, without obligation, our engineers regarding the application of HOMESTEAD LEVER-SEALD VALVES to your problems. Or write for Valve Reference Book No. 38 which shows standard Lever-Seald Valves in sizes from 1½" to 10" for pressures from 150 to 1500 lbs., cast in metals matched to service conditions.



Homestead Valve Manufacturing Co.

P. O. BOX 16 · CORAOPOLIS, PA.



The needle valve shown is regulated to admit amount of air needed to keep the pump air chamber filled.

line hammer. The seriousness of the condition resulted in a decision to remove liners and replace with a smaller bore, but the damage to pipe line anchors and tubes and refractory lining in the emulsion heater continued. To overcome this difficulty, cushion chambers with five times the capacity of a single stroke of the pumps were attached to the discharge lines. Some relief was obtained, but within a few hours the air was lost or dissolved in the emulsion so that hammer was evident once again.

An idea was developed which resulted in the constant introduction of air into the cushion chambers, obtained automatically and surprisingly at an insignificant cost which requires no attention by the operators except for original adjustment. The method employed is what is called in the plant a "snifter valve." The "snifter valve" is applied as follows:

Drill a hole in one of the cylinder heads—if duplex pumps—as only one is necessary, and tap for a half-inch fitting. Make up an assembly of sufficient half-inch pipe to connect a check valve —obviously with the clapper raising towards the pump—and a reducer for quarter-inch pipe to which is attached a bar-stock needle valve. An ell is connected to the needle valve, looking down in case fluid might leak during the discharge stroke so it will be deposited on the floor instead of being sprayed over surrounding equipment.

Operating the "snifter valve" is a simple matter. After the pump is started, open the needle valve slowly until a slight hiss of intaking air is heard each time the pump takes suction on that side. Carefully close the needle valve so that a minimum amount of air intake is obtained, then forget it.

Since installation of the "snifter valves," pumps in the system operate smoothly and auxiliary equipment show no evidence of suffering from hammer, because there is none. The original liners were installed again in the pumps and all three units in the emulsion plant may now be operated to the capacity of the plant without harmful effects.

When the cushion chamber is filled by air traveling from the pump cylinder to the discharge, the amount above the chamber requirement is carried along with the fluid.

Pedestal Support For Steam Trap

TO SUPPORT the weight of the steam trap employed for the removal of steam condensate originating in process heaters, Del Valle Gasoline Company, Castiac, California, constructs a pedestal attached to a vertical commodity line near the unit being operated. The pedestal is a circular sheet of heavy steel with a round hole in the center for the inlet pipe connections. Lugs on either side are provided for welding to the supporting pipe and is stationary and a permanent installation. To prevent vibration of the trap and fittings, including the immediate piping, a strap is placed around the discharge pipe leaving the top of the steam trap and attached to the vertical pipe to which the pedestal is fastened. Ground joint lip unions in the lines adjacent to the trap provide means of removing the unit for cleaning and inspection. Breaking out both unions leaves the trap free for horizontal movement, sufficient to lift from the pedestal without binding. With this type of trap support, there is nothing which will prevent removal.

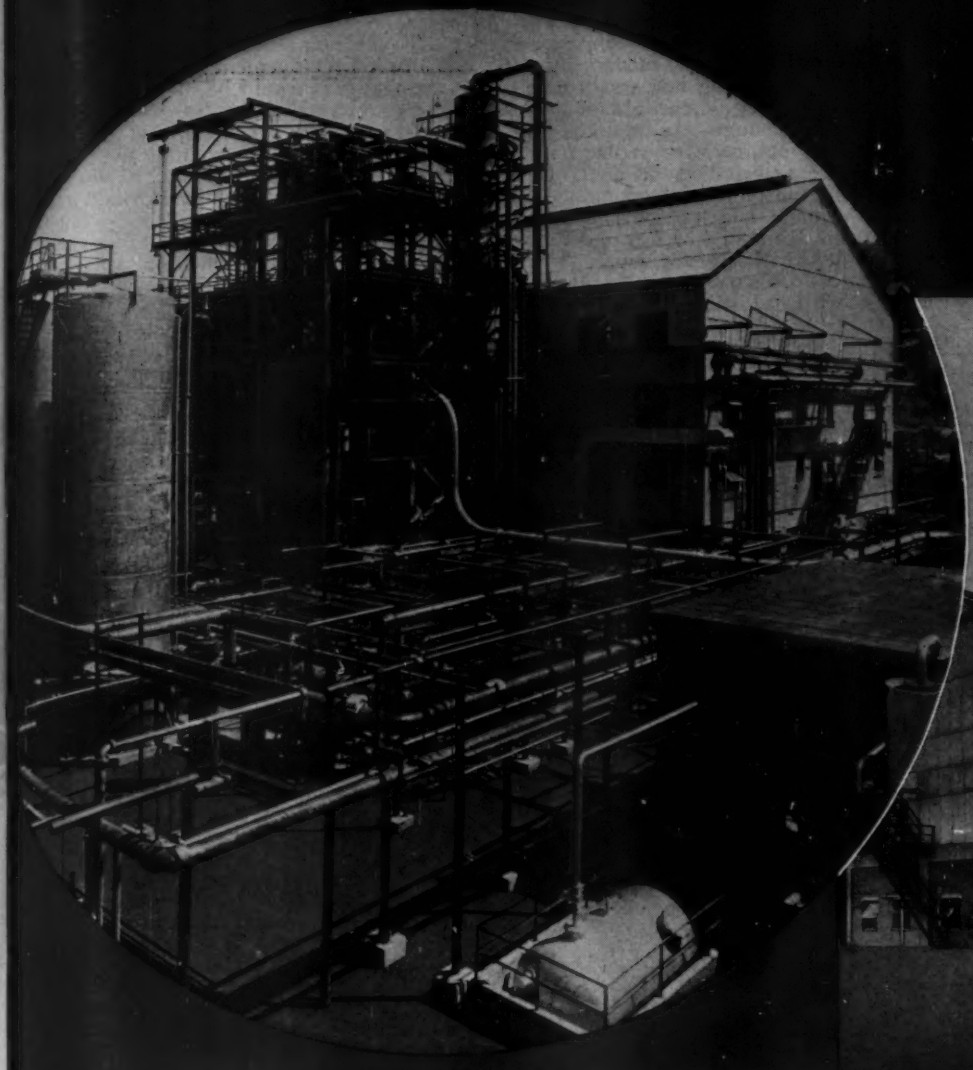
Maintenance of Refinery Waste-Water Pumps

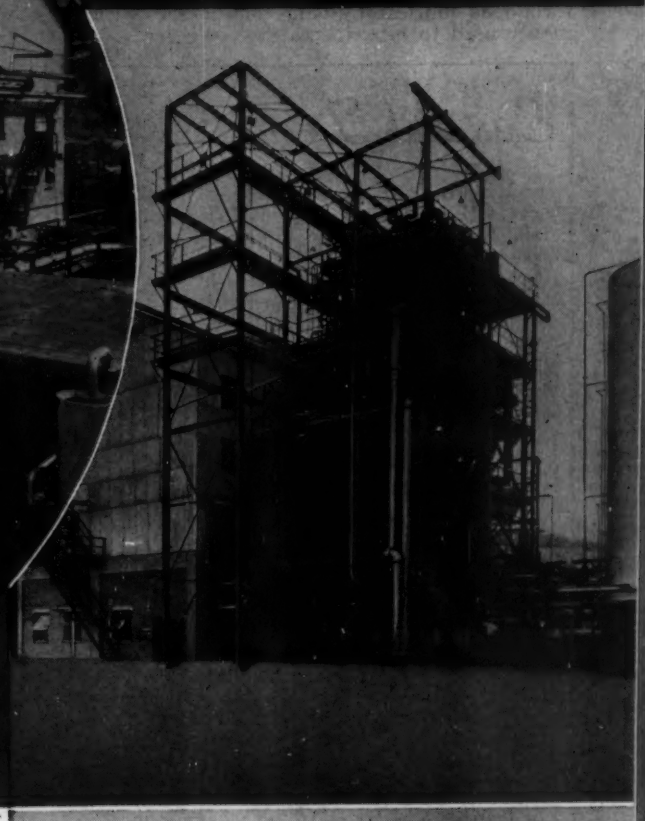
HANDLING waste water from refineries is an onerous job, and requires pumps which will withstand corrosive action of various dissolved chemicals. Hancock Oil Company of California disposes of refinery waste water with outside-end-packed duplex plunger pumps originally equipped with cast-iron plungers with no provisions for lubrication of the packing in the deep stuffing boxes. Almost every week, the maintenance crew would shut one of these pumps down to remove the worn packing and replace with fresh material. At frequent intervals the plungers would be removed for dressing down, and when replaced required a different size of packing.

To overcome frequent packing and to prevent pitting and wear on the plungers, the master mechanic, Jack Rodda, was given the green light to go ahead with any idea he might develop to keep the waste-water pump running at the least possible operating cost. Several changes were made, none of them basic, but each contributing with the other in the development of low maintenance and high operating efficiency.

The first change was in the manner of packing. The pump was not equipped with lantern rings or separators between packing to permit lubrication of the

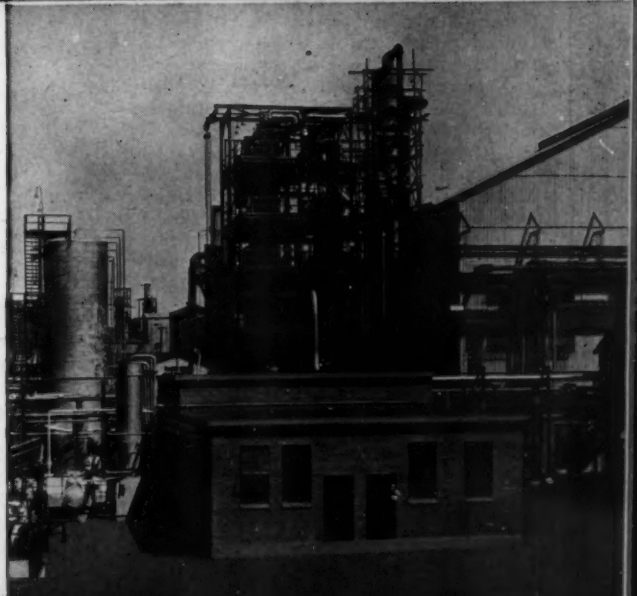
Pedestal for steam trap makes it easily accessible when servicing or inspection becomes necessary.





M·E·K SOLVENT DEWAXING PLANT

The photos on this page show three views of a 2000-barrel M·E·K Solvent Dewaxing Plant recently designed, engineered and constructed by Arthur G. McKee & Company under a Texaco Development Corporation process license.



Arthur G. McKee & Company

★ *Engineers and Contractors* ★

2300 CHESTER AVENUE · CLEVELAND, OHIO

packing and plunger. This particular pump has 5-inch plungers, and a ring was made for a stuffing box and plunger clearance of 1/32-inch. It was sawed before finishing and sweated together. Then turned to exact specifications—the 1/32-inch clearance, and 1-inch wide—broken apart and inserted, one in each stuffing box after half of the normal required packing was inserted, followed with the remainder of the packing which was compressed with the original packing gland. For lubrication, a hole was drilled through the wall of the stuffing box at a point which was measured to coincide with the inner rim of the lantern gland, or packing ring of bronze, and tapped for an oil lead line. The force-feed lubricator of the pump, commonly used to introduce steam cylinder oil into the steam line, is equipped with five pumps, one for the steam line, and one each for the packing chambers, or stuffing boxes on the plungers. The reason given for drilling the lubricating hole at the point indicated was to provide an inch-long space for lubrication and to compensate for movement of packing as the stuffing box was pressed against the packing when tightened.

The second change was in the plungers. Original plungers, or replacements of the same material as original, were taken from the pump and machined to a smooth finish. This, obviously reduced the outside diameter but was necessary to provide for following work. Next, sections of ordinary rotary drill pipe were machined inside to a slightly smaller inside diameter than the turned plunger outside diameter so that a tight fit might be obtained. The pipe sleeves for which the sections of rotary drill pipe were intended, were heated while the cast-iron plungers were chilled. The sleeves were pressed on the plungers so that the point of contact would be so close that movement of the sleeves on the plungers would be impossible.

The individual plungers were then finished on a lathe to a slightly smaller diameter than desired, so that the surface could be chrome plated. A heavy plate was applied and then ground to exactly 5 inches and polished. The plungers were attached to the pump and packed with the above-mentioned packing and placed in operation, handling normal waste water. Remarkable performance has been obtained. Instead of frequent packing of the stuffing boxes, one of these pumps has been operating continuously for more than 28 months with the same packing placed in the stuffing box when reconditioned. The plungers show a mirror finish with no perceptible scores or pits.

Esso Lab-Demousing Job Becomes Hereditary

Minnie Esso, a tawny, tiger-striped cat who had been on the payroll of the Standard Oil Development Company for 13 years, died the other day but her $4.40-a-month job as a laboratory mouser will stay in the family.

Frank Hatch, head janitor of the inspection laboratory at Bayway, New Jersey, who hired Minnie in 1933, said that one of the mouser's sons, Timmie Esso, . a jet-black youngster of 10 months, had inherited the task of keeping rats and mice out of the building of the laboratory.

The job pays $1.20 a month more than when Minnie took over—a wage adjustment, Hatch explained, to meet higher living costs. The work, he added, is also much easier because of the thorough manner in which Minnie cleaned out the rodents.

The mother cat attracted wide attention several years ago when an auditor, going over accounts at the Bayonne plant, found a recurring monthly item charged to "Minnie." Investigation showed that this was the cost of milk and salmon which she was fed. A newspaper learned of the incident and soon the story of the cat on a payroll went across the nation.

As a result, Minnie Esso was photographed and even interviewed. The idea of having a cat on the payroll led the president of Standard Oil Company (New Jersey) to write Minnie's boss asking what provisions had been made for her under the company annuity plan and other employe benefits. An insurance company suggested a policy that would provide a retirement income for Minnie to supplement social security. An organization specializing in analyzing tax liabilities offered its services to the company in behalf of Minnie.

There were also some feline letters of proposal including one from a tomcat saying that his only fault was laziness but that "as you have a good job, I am sure we could manage very nicely."

Hatch recalled that Minnie Esso was hired after rodents had caused heavy damage to laboratory records and charts. There were several other prior applicants, he said, but they apparently "got lonesome" and only stayed in the laboratory a night or two.

Timmie Esso

Minnie, however, remained faithfully on the job all during her 13 years except for a six-months' vacation cruise aboard an Esso tanker. Laboratory officials learned later that by the time the tanker docked again at Bayonne, Minnie had travelled to ports in Texas and South and Central America. During her absence, the rodents came back but so did Minnie and the sitaution was corrected.

During her tenure, Hatch estimated that Minnie had more than 100 kittens. Because she taught all of them the trick of catching mice and rats, her offspring, he said, were in great demand.

During her 13 years, Minnie became a favorite of the laboratory personnel who taught her several tricks. On her death from old age, the employes took up a collection to pay for fitting burial ceremonies.

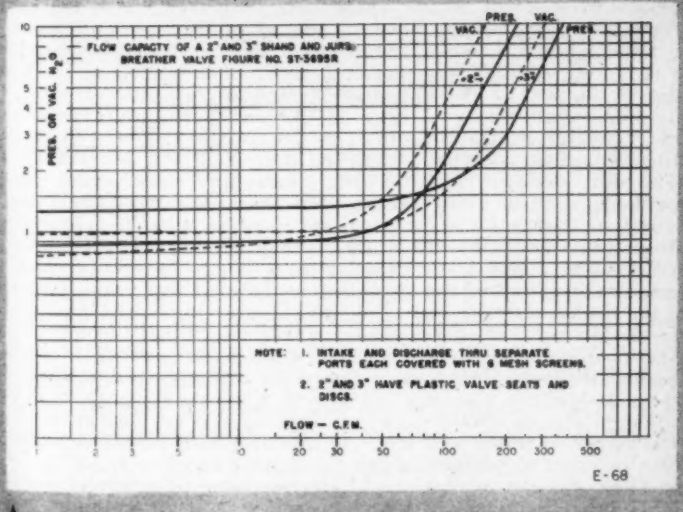
Meantime, Minnie Esso's son is carrying on satisfactorily at his mother's job and drawing her $4.40 a month on the payroll.

Cradle Simplifies Handling Hot Oil Pump

HANDLING the centrifugal unit of a hot oil pump can be a job similar to lifting a greased pig, a tricky job without adequate equipment. Overhauling is necessary at some time of the operating life of the pump, a job which cannot be done where it is set for operation. Slings are helpful for lifting from the foundation, but because of the closely spaced related equipment, it is almost impossible to place a truck near enough to haul it to the shops. To overcome all the difficulty incidental to shifting the centrifugal unit from its foundation, shipping it to the refinery shops, or even to the manufacturer for complete reconditioning, a structural steel cradle is of great advantage. The cradle in use where this illustration was made consists of I beams braced with channel iron. The skid base is designed for moving on rollers, and has cross members for skidding with a winch if necessary. The vertical sections are also of structural steel, as is the immediate foundation which carries the barrel of the pump. The I beams which support the pump on its foundation side lugs have clips welded on the upper side to prevent skidding when tilted. Rope or chain slings may be looped around the pump and the cradle for lifting from the ground to a truck, and for unloading at the shop.

This cradle will protect the pump and facilitate handling to and from the shop or back to the factory.

FLOW CAPACITY!


FLOW CAPACITY OF A 2" AND 3" SHAND AND JURS BREATHER VALVE FIGURE NO. ST-3695R
PRES. OR VAC. — OZ.
VAC.
PRES.
VAC.
PRES.
NOTE: 1. INTAKE AND DISCHARGE THRU SEPARATE PORTS EACH COVERED WITH 8 MESH SCREENS.
2. 2" AND 3" HAVE PLASTIC VALVE SEATS AND DISCS.
FLOW — C.F.M.
1 2 3 5 10 20 30 50 100 200 300 500
E-68

★ **The curves above, plotted by a major oil company from tests run on the 2" and 3" sizes, show the flow capacities of this breather under both pressure and vacuum.**

In wines you buy "taste"; in vent valves you buy capacity and reliability. Usually, the greater the capacity required, the larger the vent, the higher the cost.

Not so with S. & J. Figure ST 3695, illustrated above. Here is a pressure and vacuum breather valve, made in 2", 3" and 4" sizes which provides capacity out of all proportion to its size and cost.

From the standpoints of design, capacity, and price, it has everything to recommend it for application to bulk storage and depot tanks. Write for descriptive literature and prices.

SHAND & JURS CO.
BERKELEY, CALIFORNIA

New York • Chicago • Houston • Los Angeles • Seattle

S H A N D & J U R S

Busy Future for Petroleum Chemist

IN HIS remarks before the Petroleum Division, American Chemical Society at Chicago September 10, Bruce K. Brown, vice president of Standard Oil Company (Indiana), traced the growth of research along with growth of the industry, especially the manufacturing division. As evidence of growth he cited these comparisons: in 1921 the natural gas reserve of the nation was estimated at 20 thrillion cubic feet, now it is 135 trillion cubic feet; then the industry produced natural gasoline at the rate of 19,000,000 barrels per year, last year it produced 115,000,000 barrels; crude oil was processed at 1,200,000 barrels per day in 1921, while in 1946 the average was 4,800,000 barrels per day, and he added:

"Twenty-five years ago gasoline yield based on crude was 27 percent. Last year it was 41 percent and in modern equipment we could produce 75 percent yield if desired."

As evidence of technological development between two world wars Brown noted this accomplishment:

"During the peak of World War II the industry produced by methods of chemical synthesis a commercial grade of isooctane known as alkylate at the rate of 135,000 barrels per day. This synthesis is the largest scale organic chemical reaction yet undertaken."

In dealing with the prospect of competition between petroleum and atomic energy, he made this suggestion:

"As to petroleum's competition with atomic power, I urge that we should all worry more about whether the atomic bomb will permit us to stay on earth long enough to enjoy atomic power and fret less concerning the possible impact of atomic power on petroleum fuels."

That power from necular fission is possible was accepted in his study of what it will mean to energy from petroleum, although he cited differences of opinion in regard to power applications of atomic energy, saying:

Pluicnium vs. Petroleum

"Depending on which 'authority' you listen to, you may hear that great power plants operating on the principles of nuclear fission will be available in 5, 10, 20, 25 or 50 years. If the nature of atomic power generation is such that it is feasible only for large fixed units, it would not appear that the petroleum industry is destined to lose much of its fuel oil market in the next 25 years. On a peacetime basis only about 8 percent of our residual fuel oil production is now used competitively with coal or gas to produce power in such large fixed installations such as might be superseded by atomic power. Ocean and lake vessels use about 22 percent and railroads 27 percent. Now that the industry has available catalytic cracking processes which can increase the yield of gasoline and at the same time reduce heavy fuel yields, I do not believe it would struggle to hold all of its heavy fuel business against other contestants. Of course, if someone can devise a cheap atomic-powered automobile or airplane, we will have something real to worry about, but the 50 tons of concrete per unit which has been suggested as necessary to shield the occupants and pedetstrians from the radio-active by-products would seem to pose a considerable handicap.

The Mechanical Horse Is Here to Stay

"Until some practical scheme is invented as a substitute for a gasoline-powered automobile or airplane, our restless, independent citizens will still rely on us for fuel to power their somewhat aimless meanderings to and fro over the surface of North America. I do not know whether the horses ever worried, but 30 and more years ago horse owners and horse breeders were vastly concerned lest the advent of the automobile cause equus caballus to vanish from the face of the earth. Approximately 50 years after the invention of the automobile the horse population is about ten million—even if it hasn't kept pace with homo sapiens. As your prophet for the next 25-year period, I can only say that I think there will be plenty of petroleum-fueled engines motivating planes, trains, passenger vehicles, trucks, earth-movers, and the like in 1971.

How Much Petroleum Can the Chemical Industry Consume?

"As petroleum chemists we believe that petroleum hydrocarbons will find more and more use as a source for chemicals. The organic chemical business, great as it is, is apparently still in its infancy, and over the next 25 years there may be a fivefold expansion in it, incident to the ever greater utilization of synthetic textiles, coatings, plastics, and the like. However, even if this should occur the consumption of petroleum as fuel will continue to be infinitely more important from the standpoint of volume utilized. In this connection I am reminded of the argument advanced by the proponents of the use of agricultural raw materials (via the alcohol fermentation route) for the production of synthetic rubber. During the war, before the present world food shortage was so evident, these gentlemen argued vociferously that it was criminal to utilize our vanishing petroleum reserves to produce synthetic rubber. They did not realize that twice as much synthetic rubber per year as we apparently need in a normal year could be produced via the petroleum synthesis route with the use of no more barrels of hydrocarbons than we produce and consume in this country in a day or two out of each year.

"And so it will be with the organic chemical industry. In 1944 the gross tonnage, as reported by the U. S. Tariff Commission (exclusive of materials manufactured in ordnance plants), of all synthetic organic intermediates was 15 billion pounds. Less than 25 percent was slated as produced from petroleum. However, let us assume that in the future all organic chemicals had to be produced from petroleum by processes that would yield 1 pound of chemical per pound of crude oil utilized as a basic raw material: If this were true, we could quintuple the present output of organic chemicals, produce them all from petroleum, and still use each year only about as much crude oil as we produce in this country each month or so. The utilization of petroleum hydrocarbons for the production of chemicals and chemical raw materials has been and will continue to be a fascinating topic for petroleum technologists and source of profit to stockholders. The expansion of this technology will also be a source of increased comforts for our citizens who will utilize and benefit by these developments. Nevertheless, as a soothsayer for the period ahead, I must insist that the present fuel-type uses for petroleum will continue to be by far the greatest proportion of the volume utilized.

How Much Petroleum Products Will Be Needed?

"Now, having handled or manhandled the imponderable factors which might modify demand and supply 'guesstimates,' let us tackle the forecasts themselves. The farther ahead we look the less certain we are, but I am committed to talk about the next 25 years as well as the last 25.

"Let us break up the forecast into several segments. First, let us talk about the next 5 years. Barring a catastrophic depression, all signs point to greatly increased use of petroleum in the next 5 years and an up-grading in quality in practically all of the major products. Well recognized authorities expect that national consumption of gasoline will rise 25 percent, kerosine 7 percent, lubricants 20 percent, asphalt 35 percent, liquefied petroleum gas 25 percent, and distillate fuels for home heating 37 percent. However, the most phenomenal predicted increase is in the field of diesel fuels. It has been prophesied that the use of these materials will increase 100 percent in the next five years, largely as a result of an anticipated increase in diesel trucks and diesel locomotives. In fact, if the present rate of increase is sustained the railroads will be 40 percent 'dieselized' 10 years hence and fuel requirements for this purpose alone should be of the order of 120,000 barrels per day.

"Referring now to a longer range of prediction, an industry committee testifying before the Senate in October, 1945 attempted to estimate the total United States demand for peroleum for the next 20 years. This group, forced to express an opinion only about two months after the shooting stopped in World War II, used as a base the 1945 requirements of petroleum in the United States for home use and for export in connection with the war. They set this figure at 5.3 million barrels per day for 1945 and assumed that a large drop-off in demand would occur in the postwar period. Further, they estimated that even 20 years hence, in 1966, the total United States demand would be only about 6 million barrels per day. The postwar drop-off in demand which this committee anticipated has been much less than they predicted

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and I imagine that if they were reconvened today to make the same type of estimate they would assume that 20 years hence the national demand for petroleum products would be considerably over the 6-million-barrel-a-day figure which they used last fall.

"I do not know whether this committee fully anticipated the possible use of petroleum hydrocarbons as chemical raw materials in the decades to come but, as I already mentioned, even an extremely large expansion of this use would not consume more than about one twelfth of the petroleum that we currently produce and use.

Will We Have Enough Crude Petroleum to Meet the Demand?

"One should not throw about such immense demand figures without making some comment as to where the crude petroleum is to come from. The industry committee to which I referred reached the conclusion that while American demands 20 years hence could be met largely from domestic production there would, nevertheless, be a considerable importation of foreign crude and some production of synthetic fuels. In a free economy the same old incentive—hope of a profit—will stimulate the search for crude petroleum and should sustain the actual domestic production above the level which might prevail in an over regulated economic regime. However, this same factor would serve as well to encourage the production of crude petroleum in neighboring countries and its importation to the extent necessary to balance our national needs. Further, any increase in the cost of liquid hydrocarbon fuels based on a relative shortage of crude petroleum is bound to have a stimulating effect on the production of these fuels from natural gas, coal, or shale. If we were to draw from only one third of our present known gas reserves at the rate of 4 percent per annum we could produce 500,000 barrels a day of gasoline by variations of the Fischer-Tropsch process. The fact that two such units are currently planned for construction is a fair indication that the cost of gasoline from this source should not be substantially greater than the cost of gasoline from crude oil. Natural gas is the cheapest raw material from which to synthesize liquid petroleum by the Fischer process, but it is technically feasible to conduct the synthesis using hydrogen and carbon monoxide gas produced from coal at a somewhat higher cost and, so far as I know, no one has yet begun to worry about the depletion of our 2000-year reserve of coal. Further, we have always available the 92 billion barrels of oil in shale. From all this I draw one conclusion with which I think you will all agree; namely, that petroleum technologists will have plenty of hydrocarbons to work with throughout the next 25 years.

How Will We Use Petroleum?

"Although it is extremely improbable that non-fuel uses will consume more than a minor proportion of available hydrocarbons, even 25 years hence, it is nevertheless in the raw-material or chemical field that the most dramatic technical developments may occur.

Chemicals from Petroleum Hydrocarbons

"Petroleum hydrocarbons, from crude oil or natural gas, are the cheapest, most convenient, source of methane and its homologues and methane is the basic unit of organic chemistry. The cheapest source of the more reactive unsaturated hydrocarbons—olefins and diolefins—is the dehydrogenation of the fundamental, saturated hydrocarbons, and from the reactive olefins a legion of polymers and reaction products can be obtained. Petroleum contains the aromatic and naphthenic hydrocarbons as well. These can be segregated as needed, and, in addition processes already known can convert paraffins or naphthenes to aromatics.

"By partial oxidation of methane, hydrogen and carbon monoxide are obtained. Recombining these two permits the production of alcohols, aldehydes, ketones, and acids. Starting with hydrogen derived from hydrocarbons and nitrogen from the air one may run the gamut of nitrogen compounds—ammonia, amides, amines, nitriles, and all of the large family of nitro compounds. The Fischer synthesis plants now planned for construction to produce liquid petroleum from natural gas are currently scheduled to produce from 10 to 20 percent as much of oxygenated compounds—alcohols, aldehydes, ketones, and acids as they do hydrocarbons. These 'chemical by-products' of the oil business will be an important factor in the chemical field.

"With such a breadth of raw material it is easy indeed to set down a list of chemicals and intermediates derivable and derived from petroleum; alcohols, ammonia, aromatics, drying oils, detergents, fatty acids, fungicides, glycols and glycerine, insecticides, medicinals, nitrates, plastics, polymers, resins, rubber materials, solvents, wetting agents, and—indeed—running all the way down through the 'x, y, z's.' As petroleum chemists, we have already seen most of these—we will see all and more. Many of these developments have sprung from and will continue to arise out of the genius and hard work of members of the Petroleum Division and the enterprise of the oil companies. Many of the chemical compounds produced and to be produced can be called 'petroleum chemicals' only in the same sense that they could be called 'American chemicals'—that is, to indicate origin. Polyethylene plastic, for example, cannot recognize its parents and will never know whether the ethylene from which it sprang was produced by cracking propane or by dehydrating ethyl alcohol. Still more perplexing might be the question of the origin of the ethyl alcohol—from grain? from molasses? or perhaps from petroleum?

"One thing seems certain, namely, that the availability of organic chemicals in the next two decades will be vastly influenced by the course of petroleum refining. At the same time, the increasing application of organic chemistry to petroleum problems will be reflected in the quality of petroleum products. More and more we will synthesize relatively pure hydrocarbons to use where we now use fortuitous mixtures and the more 'chemical' our manufacture of fuels, lubricants, and specialties becomes the more we will have to offer to the field of organic chemical manufacture.

Future Fuels for Future Internal-Combustion Engines

"Leaving the raw material field and giving consideration to the fuel uses of petroleum in the future we have first to consider the internal-combustion engine. Should or should not the gas turbine and the jet in its several variations be classified as internal-combustion engines along with the reciprocating diesels and spark-ignited engines? In the turbine, combustion occurs before the engine takes hold, as is the case with the steam-driven power plant. And where, pray tell, is 'the engine part' of the jet? Having raised these questions, I leave the answers to the purists and move on to observe that all of these engines seem to prefer vaporized or atomized hydrocarbon fuels.

"Some considerable part of the total technical impetus toward improving the spark-ignited internal-combustion power plant and its fuel has, in recent years, been drawn from the need for improving aircraft engines and heavy truck engines A part, at least, of this impetus is likely to be withdrawn. More and more dieselization of heavy trucks is to be expected and airplane development (always spurred on mainly by national defense considerations and financed directly or indirectly in large part by government) seems firmly directed toward jet and turbine-jet power plants. These new developments may de-emphasize the impetus toward higher octane fuels for both planes and passenger automobiles. Nevertheless, when automobile engines are built to appreciate 100 octane fuel, we can supply it.

"The anticipated increase in diesel use both in trucks and on the railroads poses no great technical problems for us and we can cut up the barrel of crude oil that way if that is the way it is wanted.

"Over the very long pull the question of motive power for the railroads is an interesting one. In the immediate future petroleum-powered diesel engines operating electric drives seem to be clearly the answer. But coal may win out in the long run—either through the medium of a coal-fired gas turbine powering an electric drive or, perhaps, the electrification of the lines. Should that occur, atomic energy converted to electricity might eventually defeat coal!

Future Fuels for Future Ships

"Unlike planes, trains, and automobiles, ships seem to last many, many years. The coal-fired ship is passe! Fuel-oil-fired ships using steam-driven reciprocating engines are probably passe technically—but individual vessels of that type will roam the seven seas for decades to come. The steam-turbine-powered ship is with us and World War II brought a tremendous development of sea-going diesels. Those ships and their design counterparts are also apt to be with us for decades. The gas-turbine-powered ship for civilian use is yet to come.

"All in all, I believe the use of petroleum to drive civilian ships is apt to be the least changing of all major petroleum uses over the next 25 years—both as to relative quantities and as to product quality.

"I believe this will be the case even though one of the most promising uses for atomic power is ship propulsion and I assume that that problem is likely to be solved within a decade. Doubtless such plants will be installed on large naval vessels, but ocean transportation

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Future Lubricants

"Lubricants are produced or blended to meet the operating conditions of the device they serve. The more difficult the operating conditions or the more exacting the response required of the mechanism, the more is demanded of the lubricant. Certainly a lot will be demanded of lubricants for gas turbines and for machinery used in the Arctic. Vast progress has been made in this field and much more can be made as the demand warrants it. Relatively pure-compound synthesized hydrocarbon lubricants have been on the industry's shelf for years, waiting a willing buyer. Of late oxygenated polymers have become available and, of course, the potential supply of these is as great as the supply of petroleum itself.

"But nothing can ward off the tendency of hydrocarbons to decompose at sufficiently elevated temperatures and it is indeed interesting to note that the most successful lubricants for extremely high temperature conditions are 'hydrosilicon compounds' similar to hydrocarbons except that the "carbonizable" carbon atom has been replaced by a noncarbonizable silicon atom.

Wax for the Future

"There is, currently, a world-wide shortage of paraffin wax. Improved packaging methods and expanded industrial use of wax have caused this shortage. How long it will prevail is unknown. Certainly if this demand continues the industry can and will produce more wax out of ordinary petroleum materials. If need be, the Fischer synthesis of hydrocarbons could be operated in this country, as it has been in Germany, to produce up to 30 percent of waxy materials.

Natural Gas Processing

"I have already alluded to the Fischer synthesis of petroleum—using natural gas as a source of the synthesis gas. The utilization of this technique may well be one of the most important developments in the field of petroleum technology in the next 20 years. In fact an industrial historian looking back on us from the vantage point of 1971 may well say that the two most significant developments in petroleum chemistry since 1900 were: first, the development of the cracking process and, second, the synthesis of liquid petroleum from hydrogen and carbon monoxide.

Future Processing of Crude Petroleum

"The problems of refining the raw liquid from the Fischer synthesis must, of course, be considered by themselves although they are not too dissimilar to ordinary refining processes.

"Over the next two decades the crude diet of the average American petroleum refinery is apt to contain less of the conventional low-sulfur crude oil. Proportionate to the total yield of crude petroleum out of the ground there will apparently be a larger proportion of light crudes, condensate type materials from deep wells, and natural gasoline. And in the average crude hydrocarbons coming out of the ground there will apparently be more and more sulfur.

"It is interesting to speculate on the changes in refinery processing which will occur as the result of this dietary change. First, of course, there really isn't any such thing as an average refinery raw material. In many instances, particularly in the case of seacoast refineries, there may be very little change in the average crude stream. On the other hand, refineries located close to high-sulfur crudes and high-gravity crudes and condensates may feel a pronounced impact.

"To clean up the increasing sulfur content of petroleum as we get it, it may be desirable to selectively extract or otherwise 'treat out' the sulfur present in crude oils, charging stocks and heavy petroleum products as well as to treat naphthas and heating oils. As more and more sulfur flows into American refineries, there seems to be more and more reason for treating sulfur as a major by-product of oil refining than, as at present, as a nuisance. New uses for sulfur, new compounds of sulfur which are susceptible of large-scale use, seem indicated as problems well worth attack.

"The general 'lightening' of the raw material stream due to increasing proportions of natural gasoline and condensate indicate a greater possible utility for processes such as isomerization, mild reforming, selective extraction, and the like, which upgrade light petroleum fractions with less loss than occurs in cracking processes.

What Sort of Technologists for the Future?

"During the 25-year period just past, the chemical engineer moved into the field of petroleum refining technology. Throughout this period an ever-increasing proportion of the membership of this Division and an ever-increasing proportion of the total research, development, and supervisory operating personnel of the industry were men trained in chemical engineering principles as well as in chemistry. No one can appreciate more than the chemist himself the magnitude of the contributions made by the chemical engineer in the orderly, economical, and reliable handling of large-scale refining operations. Without him the technology upon which the industry now operates could not have been perfected. Automotive engineers adept at fuel and lubricant utilization problems have been with us for a long while, but in the last 10 years new types of scientists have presented their contributions—notably the physical chemist and the physicist with their assorted spectrometers and microscopes.

"What sort of petroleum technologist is apt to claim the spotlight in the refining industry in the years just ahead? My guess would be that the chemist is due for a whirl of special recognition. But he will not be the old-style petroleum chemist who dealt with the physical and chemical properties of complex hydrocarbon mixtures. He will be the 'true organiker' who will be concerned with structure, synthesis, and the creation of or selection of particular compounds for particular uses. This will necessarily be true because, except for the largest scale fuel uses, we will no longer be content to utilize chance mixtures of hydrocarbons where pure compounds or planned blends of a few individual compounds will give better results. To a very considerable extent our engineering skills have out-run our chemical performances—not, perhaps, in our research laboratories, but certainly in our manufacturing plants. The chemist must move forward so that his coworkers, chemical engineers, physicists and all of the assorted specialists in the field of petroleum refining technology can exercise their talents on the processes and products of his laboratory.

"And now I will conclude my informal dissertation on where we have been and where I think we are going. The breadth of title; that is, 'Petroleum 1921-1971' gave me room enough to talk about both technology and technologists. However, I have covered only one small facet of one of the largest and most interesting of our national enterprises, a business which is peculiarly American in technique even when it is practiced abroad. Progress in the last 25 years in the field of petroleum production and petroleum transportation has been just as thrilling as in the field of refining technology and the future for these fields holds just as great a promise of further development. There has not been a dull moment in petroleum refining technology since the Petroleum Division was founded 25 years ago. We who have seen the refiner throw away his cook books and formularies and take up Beilstein and the Chemical Engineers' Handbook are looking forward to the next 25 years with eager interest."

Carthage Hydrocol Names Dawson to Operations Post

Frank M. Dawson has been elected vice president in charge of operations, and Allen K. Brehm treasurer of Carthage Hydrocol, Inc. The company plans to synthesize gasoline and other petroleum and chemical products from natural gas in a plant to be built near Brownsville, Texas.

Dawson has been with The Texas Company for 18 years, most recently as superintendent of its Lawrenceville, Illinois, refinery.

Brehm formerly was first vice president and a director of Continental Bank & Trust Company of New York.

F. M. DAWSON

THE MONTH IN THE INDUSTRY

ACS Petroleum Division Holds 25th Convention

The Petroleum Division of the American Chemical Society celebrated its twenty-fifth anniversary during the general meeting of the society at Chicago, September 9-14.

S. S. Kurtz, Jr., Sun Oil Company, and C. L. Thomas, Monsanto Chemical Company, presided at the technical sessions of the Petroleum Division, at which a number of papers (abstracted in PETROLEUM REFINER, September, 1946, page 169) were presented. History and growth of the division was the subject of an address by Cary R. Wagner, consultant, while C. D. Lowery, Jr., Universal Oil Products Company, discussed the problems of the petroleum chemist of 25 years ago. Bruce K. Brown, Standard Oil Company (Indiana), was the speaker at the anniversary banquet (see page 152).

Gustav Egloff, Universal Oil Products Company, was elected chairman of the Petroleum Division, and A. N. Sachanen, Socony-Vacuum Oil Company, vice chairman. Kurtz, the retiring chairman, was elected a member of the executive committee, as was W. E. Bradley, Union Oil Company. Wagner was reelected secretary.

McConnell Heads Sohio Manufacturing Department

Elliott B. McConnell, who has been manager of the manufacturing department of The Standard Oil Company (Ohio), has been appointed vice president in charge of manufacturing and elected a director of the company. He succeeds George W. Hanneken who retired September 1.

After graduation with a degree in chemistry from Cornell University in 1923, McConnell became associated with Standard Oil Company of New Jersey, assigned to work in the cracking coil technical service and development division. Later he was process inspector of tube and tank units which involved visiting 15 refineries twice annually, acting as a clearing house on new developments in the process, and recommending operating improvements. He joined The Standard Oil Company (Ohio) in 1928 at the time the company was starting new cracking coils. The following year he was made assistant to the vice president in charge of manufacturing and in 1945 was made general manager of the manufacturing department.

E. B. McCONNELL

Conventions

November

7-8—Society of Automotive Engineers, Fuels and Lubricants Meeting, Tulsa.

11-14—American Petroleum Institute, annual meeting, Stevens Hotel, Chicago.

Texas-Louisiana Section ACS Hears Talk on Rubber

"Manufacture of Butylene-Styrene Type Synthetic Rubber" was the topic of Berndt K. Lyckberg at a meeting of the Texas-Louisiana Gulf Coast Section of American Chemical Society at Port Arthur on September 19. Lyckberg, who is technical manager of Firestone Tire & Rubber Company at Port Neches, preceded his talk with a motion picture which recounted the part and problems of synthetic rubber during the war.

Engraved ACS symbols were presented to W. W. Scheumann and R. F. Huhndorf in appreciation of their services as chairmen and secretary, respectively, of the section last year, by V. A. Kalichevsky, present chairman, who presided at the meeting. J. G. Eckhouse, editor of the local section publication "The Condenser" which made its initial appearance with the September issue, reported that many members of the section have promised help in carrying on this effort.

Coal, Natural Gas Moving Economically Close to Oil

Natural gas and coal as raw materials for gasoline are becoming closely competitive with crude oil according to a study presented to the American Gas Association in Atlantic City, October 7 by E. V. Murphree, vice president of Standard Oil Development Company. His subject was "Research and Development in the Oil Industry," in which he devoted considerable attention to the effect of technical developments, especially the Fluid catalytic cracking process, which is being used in converting both gas and coal into liquid products.

Concerning natural gas and coal as raw materials, he said:

"The conversion of natural gas or coal into liquid products by the Fischer-Tropsch synthesis or its modifications is based first on producing a mixture of hydrogen and carbon monoxide from the gas or coal and then reacting this mixture over a solid catalyst to give synthetic hydrocarbons. In the synthesis step proper a large amount of heat is evolved, amounting to about 1,800,000 Btu per barrel of liquid products produced. In the Fischer-Tropsch operation as developed in Germany catalyst was used in pelleted or granular form, the catalyst being stationary. In order to remove the heat, various types of reactors were used, one form of which involved having the catalyst in the annular space between cooling pipes where the thickness of the catalyst layer between the cooling surfaces was not more than ¼-inch. The capacity of the equipment was limited to ability to remove heat. For a plant to produce 10,000 barrels per day of synthetic hydrocarbons, using the German design, 128 reactors would be required having a cooling surface of 5,800,000 square feet. By use of catalyst in fluidized beds it is possible to reduce the number of reactors to four and the total amount of cooling surface to 250,000 square feet. That is, it is possible to reduce the cooling surface by a factor of over 13, which of course means a large

Trends of Operations and Changes in Stocks

Figures on crude stocks are from Bureau of Mines weekly reports; all others from American Petroleum Institute weekly reports, which are estimates on Bureau of Mines basis.

(All figures in thousands of barrels—add 000)

Trends in Week Ended:	Crude Oil			Gasoline		Gasoil and Distillate		Residual Fuel	
	Production Daily	Runs to Stills Daily	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End	Production Weekly	Stocks Week End
1945:									
January 27	4,727	4,756	221,310	14,957	88,223	4,843	33,561	9,252	51,119
February 24	4,777	4,803	219,351	15,500	95,972	4,958	28,753	9,084	46,713
March 31	4,781	4,677	223,782	14,644	98,758	4,548	26,889	9,184	41,745
April 28	4,805	4,780	223,474	14,633	94,068	4,636	28,273	9,379	39,813
May 26	4,887	4,950	222,831	15,194	89,121	4,667	29,184	9,670	38,548
June 30	4,903	4,999	220,781	15,546	86,472	4,910	32,213	9,077	40,488
July 28	4,930	4,996	218,507	16,106	86,008	4,598	36,071	9,586	42,283
August 25	4,892	4,931	211,813	15,986	84,693	4,960	39,782	9,356	46,201
September 29	4,357	3,812	222,387	11,913	79,552	3,940	43,689	7,047	46,853
October 27	4,273	4,838	224,230	15,530	74,335	5,159	43,472	8,691	45,943
November 24	4,469	4,648	219,363	15,681	83,184	4,802	45,258	8,800	47,474
December 29	4,474	4,729	218,918	14,546	95,205	5,055	36,551	8,765	42,447
1946:									
January 26	4,626	4,553	220,544	13,622	107,737	5,720	29,498	8,411	39,722
March 2	4,726	4,779	229,430	13,871	104,462	5,888	25,148	8,634	38,441
March 30	4,425	4,684	221,214	13,896	104,715	5,357	28,240	8,738	37,746
April 27	4,672	4,685	221,689	14,228	99,631	5,568	30,466	9,204	39,404
May 25	4,759	4,857	222,214	14,322	95,769	5,463	32,973	8,908	43,368
June 29	4,957	4,854	223,883	14,500	92,333	5,408	37,762	8,828	46,447
July 27	4,926	4,896	222,740	14,535	88,626	5,817	44,316	8,217	49,517
August 24	4,836	4,866	225,672	14,639	86,251	5,649	51,405	8,126	52,061
September 28	4,778	4,829	221,903	14,538	85,854	5,450	57,903	8,158	56,914

reduction in investment along with a large reduction in maintenance and operating cost. The use of catalyst in fluidized form in the Fischer-Tropsch process has been one of the outstanding advances in making this process commercially interesting in this country for conversion of gas and coal into liquid products.

There have been advances too, in the types of catalysts used. The catalysts used by the Germans gave very paraffinic products and the gasoline obtained was low in octane number. The catalyst mainly considered for application in this country is of a different type and gives a gasoline of relatively high octane number. Improvements have also been made in methods of producing synthesis gas. One process for production of synthesis gas being considered commercial for both natural gas and coal involves partial combustion with oxygen to produce the hydrogen-carbon monoxide gas mixture required. In the case of coal, of course, steam is used along with the oxygen.

"From an economic standpoint, as brought out above, production of liquid products from natural gas using a modified Fischer-Tropsch operation, appears reasonably attractive economically at the present time. The cost of producing gasoline in this way may be slightly lower than the cost of production of gasoline from crude oil. There is, however, a substantially higher investment involved in the production from natural gas. In the production of liquid hydrocarbons by the Fischer-Tropsch synthesis with coal some light hydrocarbon gas is produced and this may either be converted back again to hydrogen and carbon monoxide or may be sold as high Btu gas.

"Some rough figures on production of both gasoline and gas from coal may be of interest. A plant to produce about 9000 barrels per day of gasoline along with 1800 barrels of gasoil from coal, using the fluidized technique as discussed above, is estimated to cost roughly $42,000,000. In addition to the gasoil and gasoline produced, this plant would produce slightly under 40,000,000 cubic feet of gas per day of around 1000 Btu. If this gas is credited with 25 cents per thousand cubic feet and suitable credit made for the gasoil produced as well as certain chemicals, then the cost of gasoline from this plant based on coal at $2.50 per ton comes to roughly 7¼ cents per gallon. This is not a great deal more than the cost of production of similar grade gasoline from crude oil at present crude prices. The investment, however, is much higher, for the gasoline-from-coal plant than would be involved in making the equivalent quality of gasoline from crude oil and the above cost includes no return on the added investment.

"In addition to the other products produced from natural gas or coal, there are produced relatively large amounts of chemicals such as ethyl alcohol and higher alcohols and in addition ketones and acids. In areas where these chemicals can be disposed of their production represents an appreciable credit to either the natural gas or coal operation. It seems very likely in the future that chemicals produced in this way are going to have an important place in the organic chemical industry in the United States."

Standard of Indiana Completes Fluid Unit

Standard Oil Company of Indiana has completed its first Fluid catalytic cracking unit at the Whiting, Indiana, plant, which was inspected October 8 by a party representing all phases of newspaper and publication groups. The catalytic unit represents part of a total expenditure of $150,000,000 which this company will make during the immediate postwar period. A second similar unit is under construction at Whiting, one is being built at Sugar Creek, Missouri, and a third will be added to the company's plant at Casper, Wyoming.

A new administration building as well as facilities for the engineering and research activities of the manufacturing department will be built at Hammond, adjacent to the Whiting location. These facilities will be completed in 1947.

A description of the catalytic units and accessory processes was included in the remarks of Dr. R. T. Nyrick, assistant plant manager, as follows:

"Each unit will have a feed capacity of 25,000 barrels of gasoil per day and each will produce about 11,600 barrels of high-quality gasoline daily. In addition each unit will produce 2600 barrels per day of butane suitable for feed to an alkylation unit for the production of high-octane aviation gasoline components or for use in the production of other chemical compounds. Two streams of cycle gasoil will be produced totaling 9700 barrels daily, half of which will be suitable for domestic heating oil and the balance will be charged to thermal cracking units and converted into more gasoline. There will be produced from each catalytic cracking 7,500,000 cubic feet per day of excess gas for use in the refinery or for making chemical compounds."

Socony-Vacuum Appoints Montgomery to New Post

William H. Montgomery has been appointed manager of the industrial relations department of Socony-Vacuum Oil Company, succeeding W. H. Zabriskie, who has been appointed secretary of the manufacturing committee. For the past three years Montgomery has been manager of the company's Lubrite Division refinery at East St. Louis; Charles P. Baker succeeds to the latter post.

Montgomery started in the oil business at Bayway, New Jersey, in 1926. From 1928 to 1941 he was at the Palembang refinery of Standard-Vacuum Oil Company and was assistant general manager when he left the Dutch East Indies just before the war.

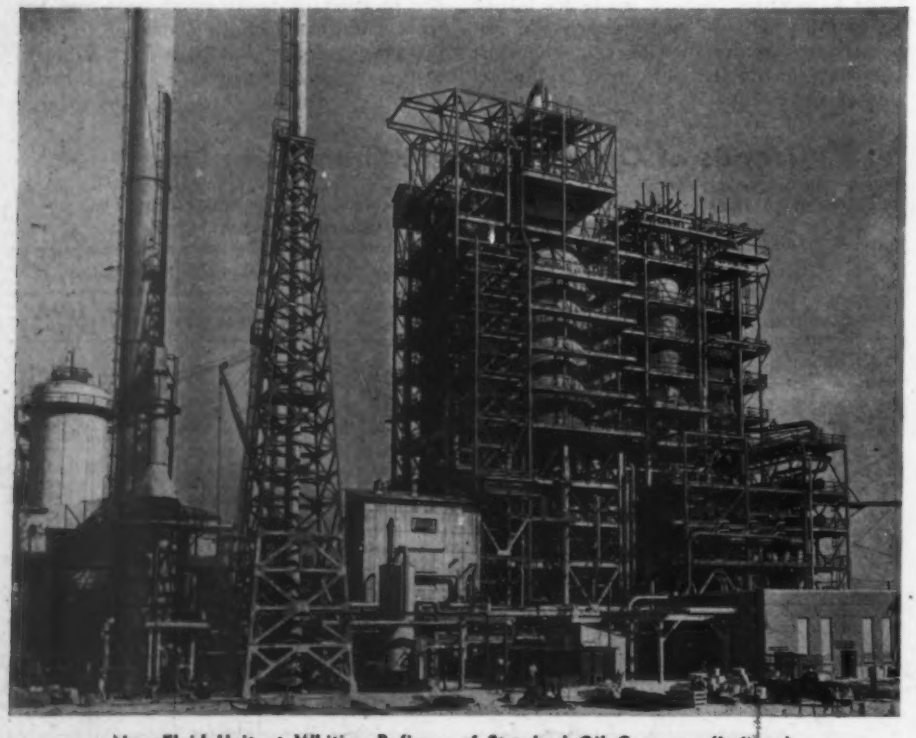
Baker had been employed as technical adviser to the operating department of Magnolia Petroleum Company at Beaumont prior to January 1 of this year when he went to East St. Louis as assistant manager, and on March 1 was advanced to general plant superintendent. He was an Army major assigned to PAW as chief of the aviation section during the war.

Shell Promotes Merkus, Cutting, Faulk and Dunlap

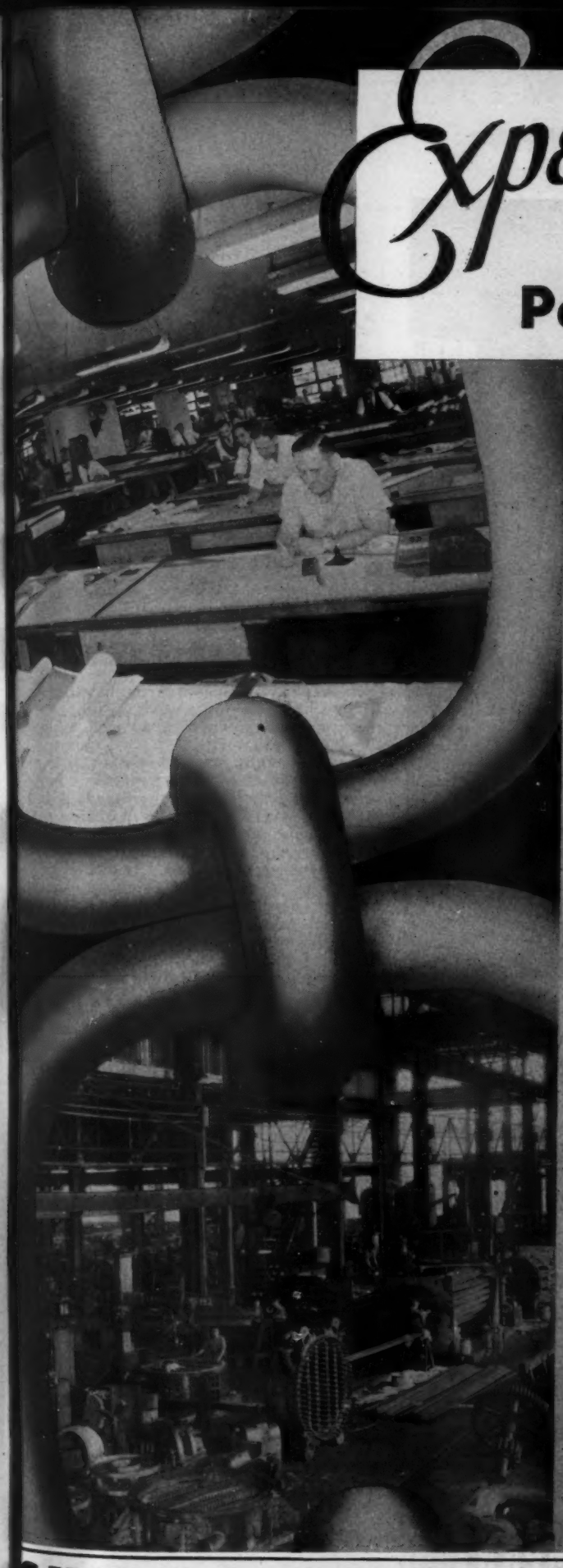
Dr. P. J. Merkus, Jr., until recently manager of the research and development department of Shell Oil Company at New York, has been appointed assistant to the vice president in charge of manufacturing. He succeeds H. D. Dale who was appointed manager of the company's Wood River, Illinois, refinery.

Dr. Merkus began his career with Shell Oil Company in 1934, immediately after receiving his doctor's degree in chemical engineering from the University of Michigan. Thereafter he progressed in the research and development department, becoming manager of the department in 1943, a position he held until his present appointment.

F. C. Cutting, assistant manager of the research and development department, succeeds Dr. Merkus as manager. Since joining the company in 1925, upon graduation from the University of Mich-



New Fluid Unit at Whiting Refinery of Standard Oil Company (Indiana)



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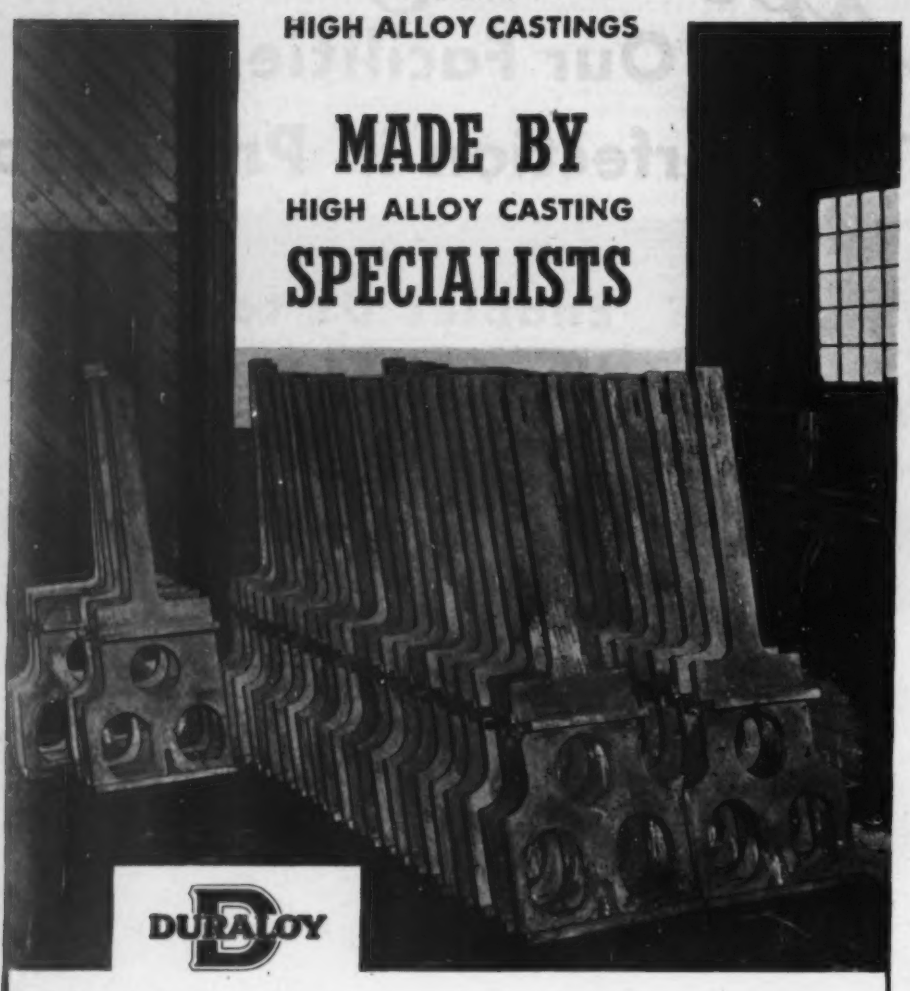

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DR. P. J. MERKUS, JR.

igan, he has advanced through various technical and administrative positions at the company's refineries, as well as in the New York office.

Roy W. Faulk, former assistant superintendent at the Norco refinery, has been named assistant superintendent at Houston, where he will be in charge of the topping, cracking and dispatching departments. After graduating from Southwestern Louisiana Institute in 1929 with a degree in chemical engineering, Faulk became a tester in the Houston laboratory. He rose through the administrative and operating departments of the company's refineries, and returns to Houston after an absence of 10 years.

John B. Dunlap, manager of the cracking department at Houston, succeeds Faulk as assistant superintendent at Norco. Dunlap graduated from the Uni-

F. C. CUTTING

THE MONTH...

versity of South Dakota in 1928 with a degree in chemistry, and immediately joined Shell Oil Company as a gauger in the Arkansas City refinery. During the following 12 years, he gained experience in the company's refineries until, in 1942, he was appointed manager of the cracking department at Houston.

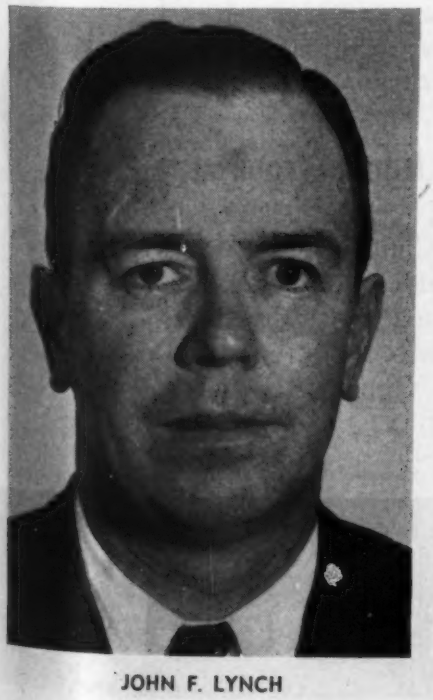
Downey Appointed Houston Manager Shell Chemical

Bernard M. Downey has been appointed manager of the Houston plant of Shell Chemical Corporation, where he succeeds C. W. Humphreys who recently was transferred to San Francisco as manager of operations.

Downey started with Shell Oil Company of California in the maintenance department at Martinez refinery in 1925, and in 1931 transferred to Shell Development Company as a machinist at Emeryville. After a few months he returned to Martinez as a machinist in the engineering department of the chemical company, and during the next 10 years was operator, chief operator and supervisor until named superintendent of Shell Chemical Company's alcohol plant at Martinez. In 1943 he became superintendent of the Dominguez plant where he remained until his present assignment.

La Gloria Corporation Announces Promotions

T. S. Scibienski and John F. Lynch recently were elected vice presidents of La Gloria Corporation Corpus Christi, Texas. Lynch also represents La Gloria Corporation on the board of directors of Carthage Hydrocol, Inc. John J. Sheerin has resigned as vice president of La Gloria Corporation but will continue as a director, and E. C. Will has resigned as vice president and will remain with the company as a consultant. Frank H. Stone has been appointed to succeed Lynch as superin-



JOHN F. LYNCH

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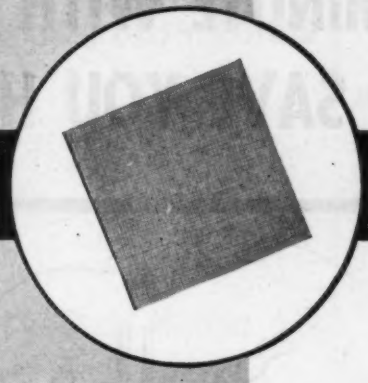

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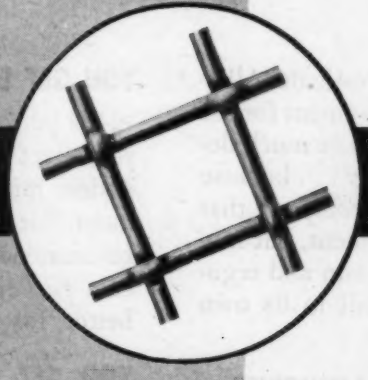

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Your prescription is supported by two important advantages: First, CESCO Respirators permit *free breathing*, at the same time giving workers *full protection* from dust and fume dangers. Second, CESCO Respirators are worn with minimum interference with normal comfort—every possible comfort feature is incorporated into CESCO products.

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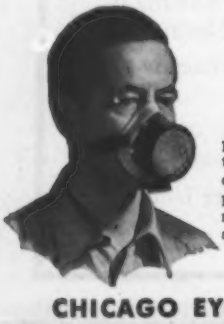
Cartridge-type respirator for protection from light gas and vapor concentrations. Rubber face cushion shapes to varying facial contours, provides air-tight seal, comfortable fit.



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FRANK H. STONE

tendent of the company's plant at Falfurrias, Texas.

Lynch has been with La Gloria Corporation since 1944. He attended Washington University, St. Louis, and for nine years was with Shamrock Oil & Gas Company at Amarillo, Texas, and worked in production, natural gasoline and refining departments, advancing to assistant superintendent. In 1939 he went with Fletcher Oil Company, Los Angeles, as refinery superintendent, and later was manager of that company's refining and marketing operations.

Stone has been resident engineer at Falfurrias since 1944. He had a degree in chemical engineering from Texas Technological College, and was with Shamrock Oil & Gas Company as chief engineer before joining La Gloria Corporation.

Oblad, Carmody Now With Texas Research Foundation

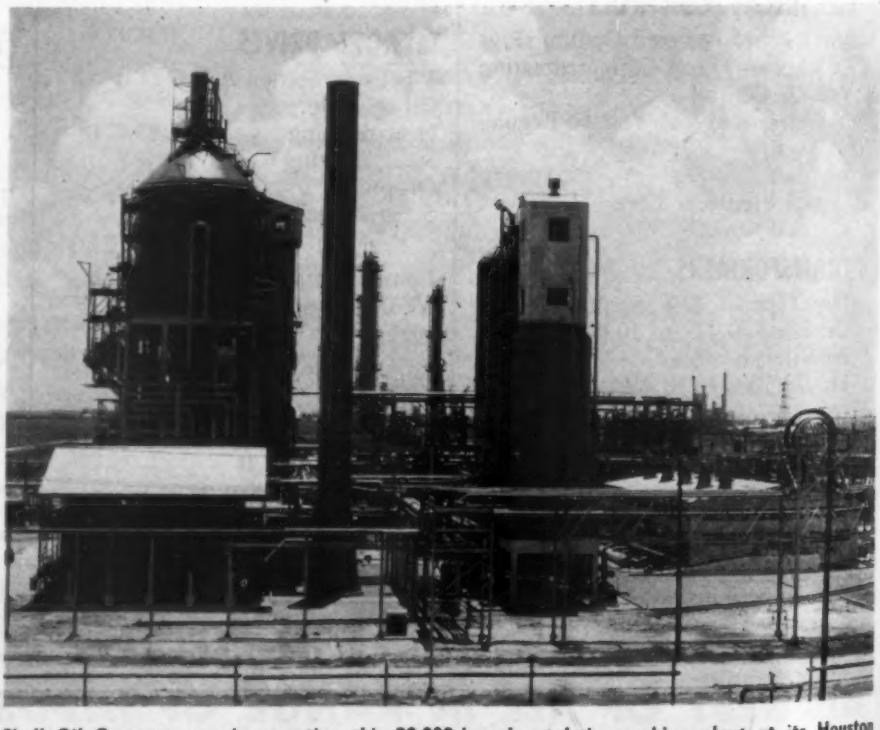
Dr. Alex G. Oblad and Dr. D. R. Carmody, recently with the field research laboratories of Magnolia Petroleum Company, Dallas, have joined the staff of Texas State Research Foundation, Dallas, Oblad as principal chemist, and Carmody as supervisor in charge of process research and acting supervisor of organic chemical research.

Oblad received his Ph.D. in physical chemistry at Perdue in 1937, having previously had B.A. in chemistry and M.A. in physical chemistry at University of Utah. Following graduation he joined the research staff of Standard Oil Company (Indiana), and in 1942 went to the Magnolia Petroleum Company laboratory where he was chief of chemical research at the time he left for his present connection.

Carmody had his B.S. at St. Ambrose College and M.S. and Ph.D. from University of Iowa. Following his doctorate in 1937 he was for six years with Standard Oil Company (Indiana) where he worked in exploratory research in hydrocarbon chemistry. In 1943 he went with Maytag Company as chief chemist and to organize research in utilization of farm products. In 1945 he became research supervisor in charge of process research with the Magnolia laboratory.

Lion Oil Company Building Nitric Acid Plant

Lion Oil Company has started construction of three 45-ton-per-day ammonia oxidation units for production of nitric acid at its Chemical Division plant near El Dorado, Arkansas. The addition will increase nitric acid capacity of the plant by approximately 50 percent.



Shell Oil Company now is operating this 20,000-barrel catalytic cracking plant at its Houston refinery. This unit was started during the war period and is the first built specifically to use microspheroidal catalyst.

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The Pistol Grip weighs only 3 pounds — no more than a 12" stilson wrench. It provides the operator with one-hand control for cleaning small, straight tubes of ¼" to 1" I.D. in sterilizers, hot water heating units, lube oil heaters, oil pre-heaters, heat exchangers and other small bore tube apparatus.

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2. Unusually fast action (up to 3500 rpm working speed) permits the use of standard Wilson cleaning accessories.
3. Scavenging agent is carried down the hollow shaft to the cutter-bit . . . even coal oil can be used when it is economically available.
4. Special Rotary Seal at front end prevents leakage of scavenging agent and eliminates stuffing box and packing troubles.
5. Even sagged tubes can be cleaned with Pistol Grip. The hollow shafting has sufficient "give" to follow the contour of the sag without damaging tube walls.
6. Pistol Grip provides the operator with instantaneous one-hand control of speed and power.

Actual photo showing trigger control

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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by The Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

The Heat of Vaporization as a Function of Pressure and Temperature. J. E. HAGGENMACHER. *Jour Amer. Chem. Soc.* **68** (1946) pp. 1633-34.

From an equation for the vapor-pressure curves of liquids the heat of vaporization is determined as a function of temperature and pressure. The equation is applicable to all substances the critical pressure and temperature of which are known and for which vapor-pressure data are also known. Calculated values of the latent heat are compared with calorimetrically-measured heats of vaporization in the case of several substances. The agreement is close.

A Generalized van der Waals Equation of State for Real Gases. G. SU AND C. HOU CHANG. *Ind. & Eng. Chem.* **38** (1946) pp. 800-802.

The authors propose a modification of van der Waals equation in its reduced form known as the theorem of corresponding states. The proposed generalized equation includes two universal constants. Comparison of calculated and observed pressures for many gases indicates total average deviations less than 3 percent. The proposed equation holds almost up to the critical density.

Generalized Equation of State for Real Gases. G. SU AND C. HOU CHANG. **38** (1946) pp. 802-803.

In the present study of generalized thermodynamic properties of real gases as made by the authors, two generalized equations of state have been described. One is a generalized form of the Beattie-Bridgeman equation, and the other that of van der Waals equation. Both of these equations are applicable almost up to the critical density. The purpose of the present article is to present a generalized equation that will be applicable from low densities to about twice the critical density. This equation includes three constants the values of which were determined. The values of these constants are the same for all gases. The equation was found to be valid up to twice the critical density with an average deviation of 2 percent or less for each gas.

Modified Law of Corresponding States for Real Gases. G. SU. *Ind. & Eng. Chem.* **38** (1946) pp. 803-806.

The author proposes a modification of the law of corresponding states. A term called the ideal critical volume is defined, and the ratio of volume to ideal critical volume is called the ideal reduced volume, to be used in place of the reduced volume. It is shown that, for 17 gases within the temperature and pressure ranges studied, the over-all average deviation is 1 percent. The value of the critical ratio is not a restriction or a criterion for the applicability of the modified law.

Purification and Properties of 29 Paraffin, 4 Alkylcyclopentane, 10 Alkylcyclohexane, and 8 Alkylbenzene Hydrocarbons. A. F. FORZIATI, A. R. GLASGOW, JR., C. B. WILLINGHAM, AND F. D. ROSSINI. *J. Res. Natl. Bur. Stand.* **36** (1946) pp. 129-36. (Res. Paper No. 1695.)

The report covers the work done in the purification of 51 hydrocarbons and the measurements of refractive index, density, boiling point, pressure coefficients of the boiling points at 1 atmosphere, freezing point, and the calculated impurity. Purification was effected either by distillation or azeotropic distillation in columns of 100 or more theoretical plates. Refractive indexes were determined with a precision refractometer using standard hydrocarbons as reference. Densities were determined by means of a density balance. Freezing points were determined from time-temperature freezing and melting curves and purity of the samples was calculated from the freezing point for zero impurities and values of the cryoscopic constants. The data are presented in detail.

Heats of Formation, Hydrogenation, and Combustion of the Monoolefin Hydrocarbons through the Hexenes, and of the Higher 1-Alkenes, in the Gaseous State at 25° C. E. J. PROSEN AND F. D. ROSSINI. *J. Res. Natl. Bur. Stand.* **36** (1946) pp. 269-75.

Revised figures for the heats of formation, hydrogenation, and combustion of the olefin hydrocarbons are given. Slight revisions were made in the selected best values for heats of formation of water and carbon dioxide, and for values of the specific heat used for converting the heats of hydrogenation from the temperature of measurement, 82° C., to 25° C. New data for the hexenes and the higher-molecular-weight 1-alkene hydrocarbons, using data on specific heat and heat of hydrogenation of the monoolefins, and new data on the heats of formation of the paraffins are also given. For 2 pentenes, 14 hexenes, and all the higher 1-alkene hydrocarbons, the data were derived by a procedure involving correlation of the heat of hydrogenation with structure and the use of constants determined from the available data on 4 butenes, 4 pentenes, 3 hexenes and 1 heptene.

Physical Properties of 2- and 3-Methylthiophene. F. S. FAWCETT. *Jour Amer. Chem. Soc.* **68** (1946) pp. 1420-22.

Thiophene was made from n-butane and sulfur by a process recently developed in the Socony-Vacuum Oil Company laboratory. If pentanes are used, methylthiophenes are formed. Two of these methylthiophenes were

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, 33rd, Federal, and Dearborn Sts., Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only one gram quantities, please inform the Registry.

2,2-Dimethylbutanol-4
2-Methylpentanol-3
3-Methylpentanol-2
Methyl sec butyl ketone
Methyl tert butyl ketone
2-Methyl-n-butyraldehyde
2-Methylvaleraldehyde
Benzoylacetic acid
Desoxalic acid
o-Quinone
Diphenylmethyl bromide and chloride
Chloroacetylene
1,4-Butanediol
N,N-Diisopropyl aniline
1,3-Dimethyl-4,6-di (chloromethyl) benzene
1,3,5-Trimethyl-2,4-di (chloromethyl) benzene
4-4'-Di (chloromethyl) biphenyl
1,4-Di (chloromethyl) naphthalene
9,10-Di (chloromethyl) anthracene
Di (4-chloromethylphenyl) methane
1,4-Dichloro-2-butene
Cyclohexadiene-1,3 (5 lbs.)
Pure aliphatic hydrocarbons, about C_{22}
3-Methylcyclopentanol
1-Methylcyclopentanol
Hydroxymethyl cyclopentane
2-Methylcyclopentanone
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purified by distillation and the freezing point, vapor pressure, refractive index, density, viscosity, and specific dispersion were determined. Two crystalline forms of 3-methylthiophene were found; the lower-freezing form having the lower heat of fusion than the higher-freezing form, and, over the entire range of its existence is metastable with respect to the higher-freezing form. Data secured in the work are presented in detail in tabular form.

Chemical Compositions and Reactions

Isomerization of n-Butane Catalyzed by Aluminum Bromide. A. G. Oblad and M. H. Gorin, *Ind. & Eng. Chem.* **38** (1946) pp. 822-28.

Although the isomerization of n-butane has become an important commercial source of isobutane, much more is known about the practical aspects of the reaction than about its chemistry. The isomerization of n-butane with aluminum bromide as catalyst was studied in the Magnolia laboratory several years ago. In the course of the investigation the effect of various promoters was determined. Oxygen was found to be outstanding as a promoter for the reaction, and in the ensuing work most of the studies were concerned with the effect of oxygen. The rate of isomerization is first order with respect to n-butane concentration and, at a given temperature, depends on aluminum bromide concentration, oxygen concentration, and the amount of surface. The rate of isomerization decreases with time because of oxygen consumption. The factors that influence oxygen and catalyst consumption were determined, and the promotional effect of oxygen was compared to that of other substances. The mechanism of the promotion of aluminum bromide as an isomerization catalyst is discussed. It is suggested that surface is necessary to assure a polar medium in which the reactions can take place. Data secured in the course of the work are presented in considerable detail in nine tables and seven figures. A bibliography of eight references is included.

Alkylation of Thiophene by Olefins and Alcohols. W. M. Kutz and B. B. Corson. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 1477-79.

Thiophene was alkylated by propylene, butylene-1, isobutylene, amylene, cyclohexene, isopropyl alcohol, and tertiary butyl alcohol. An alumina-silica type catalyst (Filtrol X-143) proved to be satisfactory for the alkylation of thiophene. Phosphoric acid can also be used, but other typical alkylation catalysts are unsatisfactory, e.g., aluminum chloride, ferric chloride, stannic chloride, hydrogen fluoride, boron trifluoride-dimethyl ether complex, and sulfuric acid. Suitable conditions were not found for the alkylation of thiophene with ethylene. The properties of the monoalkylthiophenes are tabulated. Data are also given on the higher-boiling products.

Isomerization of Alkanes. III. The Water-Aluminum Halide Reaction and Isomerization of n-Butane with the Reaction Product. R. C. Wackher and H. Pines. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 1942-46.

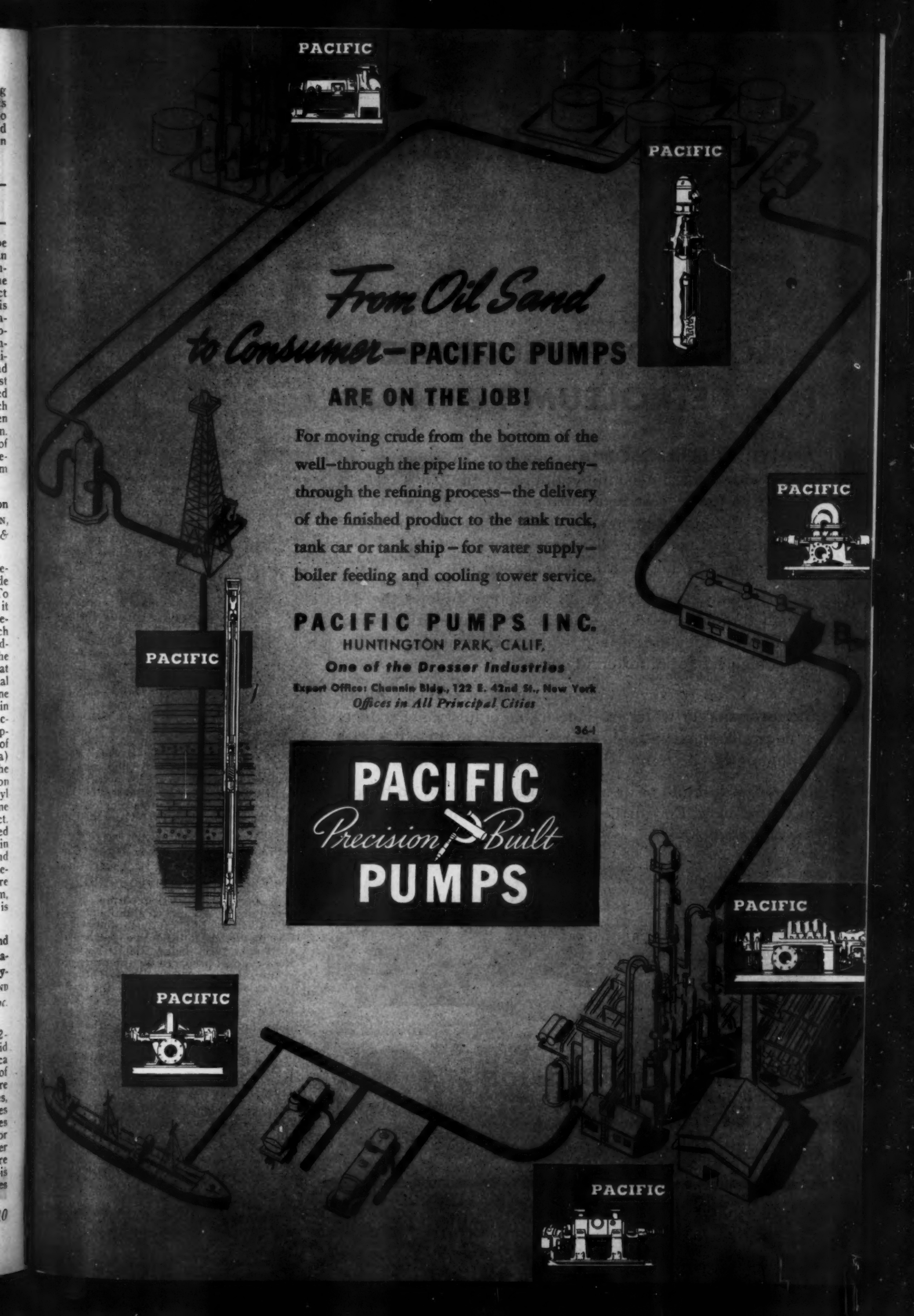
In previous papers the authors have shown that the isomerization of hydrocarbons in the presence of aluminum bromide or aluminum chloride can be greatly affected by impurities present in the reagents or introduced through improper experimental technique. In the present paper the results on the effect of a third possible impurity, water, is considered in its effect on the isomerization of n-butane, using aluminum chloride and aluminum bromide. The compounds formed by the reaction of aluminum chloride or aluminum bromide and water comprise an isomerization catalyst for n-butane that does not require added hydrogen halide promoter and which yields only small amounts of hydrogen halide during the isomerization reaction. A mechanism for the isomerization of alkanes using a catalyst produced by reaction with water on the aluminum halide is suggested.

Mechanism of Catalyzed Alkylation of Isobutane with Olefins. M. H. Gorin, C. S. Kuhn, Jr., and C. B. Miles. *Ind. & Eng. Chem.* **38** (1946) pp. 795-799.

An extensive study of alkylation reactions catalyzed with hydrogen fluoride and aluminum bromide was made. To explain the mechanism of the reaction it was found convenient to distinguish between the possible mechanisms by which primary and secondary isomeric products were formed and to introduce the concept of direct alkylation as that process that leads to the preferential formation of a single primary alkane isomer. The principal alkane isomers in isobutane alkylation are qualitatively accounted for on the basis of an approach to thermodynamic equilibrium of the permissible product isomers via (a) simple one-carbon hydride shifts in the catalyst-olefin complex and (b) addition to this complex of methyl and isopropyl fragments from the polarized isobutane molecule or from the primary product. Primary alkylation products are defined as those formed preferentially and in high yields at low temperatures and short residence times. The results secured in the course of the work are presented in some detail in tabular form, and a bibliography of 10 references is included.

Inter-polymerization of Isobutene and 2-Methyl-2-butene Using an Alumina-Silica Catalyst. Composition of the Hydrogenated Nonenes. G. C. Johnson and F. S. Fawcett. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 1416-19.

When isobutene and 2-methyl-2-butene react in the presence of a solid catalyst composed of alumina and silica at temperatures in the neighborhood of 110° C., the main product is a mixture of nonenes. Other products are octenes, decenes, and trimers. The nonanes formed by hydrogenating the nonenes have special properties as a fuel for internal-combustion engines. The power output of the engine under rich-mixture conditions—i.e., high fuel-air ratios—is remarkably high. The special properties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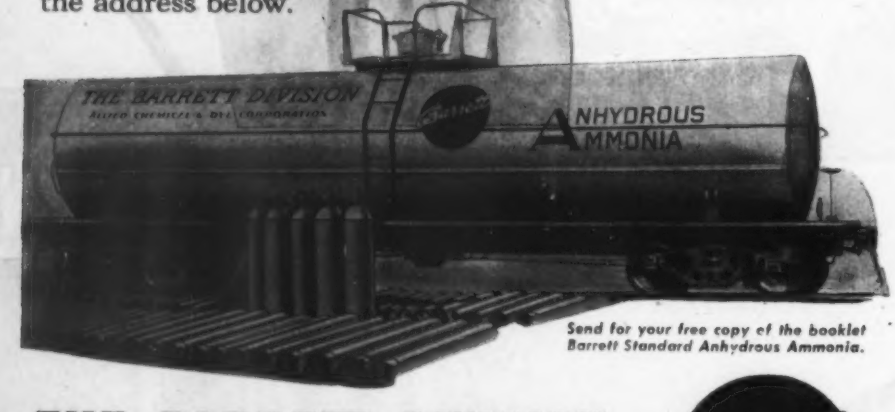

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depend upon the composition of the nonanes, especially upon the total content of tetramethylpentanes. At 110° C. and 500 psig pressure, the inter-polymerization reaction led to a mixture of nonanes which on hydrogenation yielded 2,2,4-trimethylhexane 29 percent; 2,4,4-tribethylhexane 30 percent; 2,2,3,4-tetramethylpentane 31 percent; 2,3,3,4-tetramethylpentane 9 percent; and about 1 percent of unidentified compounds. These nonanes are the same as those resulting from the reaction of t-butyl alcohol with t-amyl alcohol in the presence of 60 percent-by-weight sulfuric acid at a temperature below 80° C. The physical properties of the four nonanes are given. The mechanism of the reaction is briefly considered.

Styrene Production by Catalytic Dehydrogenation. J. M. MAVITY, E. E. ZETTERHOLM, AND G. L. HERVERT. *Ind. & Eng. Chem.* **38** (1946) pp. 829-32.

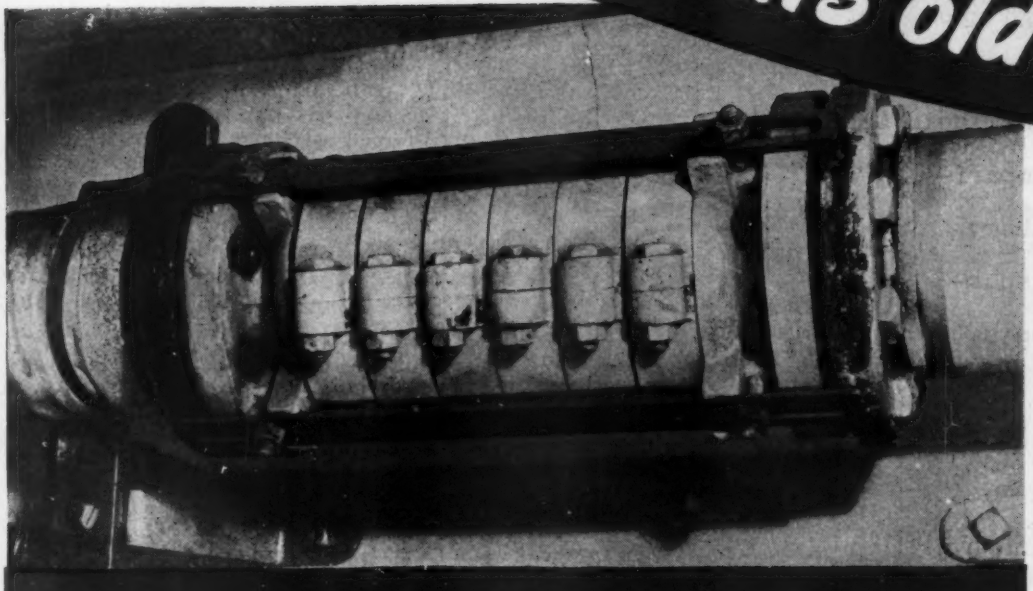
It has been demonstrated that the catalytic dehydrogenation of ethylbenzene to styrene can be effected advantageously at pressures below atmospheric. Another method that avoids the necessity of subatmospheric pressures involves effecting the dehydrogenation in the presence of some added material, as for example, benzene. Benzene is relatively stable under the conditions used and has no deleterious effect on the chromia-alumina catalyst. It serves to reduce the partial pressure of ethylbenzene and also to act as a heat carrier to supply the heat needed in the dehydrogenation reaction. Dilution with benzene decreased conversion at high ethylbenzene space velocities, but increased it at low space velocities. At any given conversion, dilution improved styrene yield and reduced carbon formation. Reduction of pressure below atmospheric, in addition to the use of benzene diluent, further improved the selectivity of the dehydrogenation reaction. Under the preferred conditions the average conversion in a series of simulated recycle runs was 34.8 percent, and the ultimate styrene yield, 89.7 percent by weight. The ratio of benzene to ethylbenzene by weight was 5. Atmospheric pressure was used. The space velocity of ethylbenzene was 3.8 and the temperature 581° C. at the catalyst bed inlet.

Preparation of a Raney Nickel Catalyst. A. A. PAVLIC AND H. ADKINS. *Jour. Amer. Chem. Soc.* **68** (1946) p. 1471.

A procedure for preparing Raney nickel from the nickel aluminum alloy is described. The catalyst obtained by this method is more active, particularly at temperatures below 100° C. than is Raney nickel prepared by any other procedure known to the authors. The catalyst as described is active for the hydrogenation of esters to alcohols at 25 to 50° C., and in various other hydrogenations at lower temperatures than are feasible with other nickel catalysts.

The Catalytic Oxidation of Ethylene. G. H. TWIGG. *Trans. Faraday Soc.* **42** (1946) pp. 284-91.

When ethylene and air are passed over a silver catalyst at 200° to 350° C. the reactions are complicated even though the products are ethylene oxide, carbon dioxide and water. The catalyst is made by plating glass fibers with silver. The surface of the catalyst is



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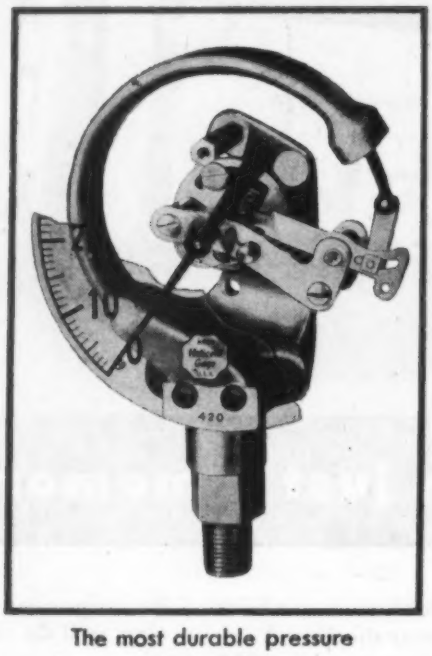

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highly extended. The adsorption of gases on its surface is readily measured. Oxygen was adsorbed as atoms and it was found that no other reactant was adsorbed. Surface layers of oxygen could be formed, following which the reaction vessel could be pumped out and other gases allowed to come in contact with the oxygen layer. By this procedure the individual steps in the reaction chain could be studied. The adsorption of oxygen by the catalyst caused an increase in electrical resistance, the amount of which increase was directly proportional to the fraction of the surface covered by the oxygen. If the adsorbed oxygen was removed by reaction with another gas, the electrical resistance was reduced to its initial value. Thus a means is provided for directly estimating the oxygen adsorbed on a silver surface. When air was passed over the catalyst, the surface was about two-thirds covered. When ethylene was added to the air, the surface concentration fell to about one-third coverage. Ethylene can be oxidized either to ethylene oxide, or directly to carbon dioxide and water. Ethylene oxide isomerizes to acetaldehyde, which in turn can be oxidized rapidly to carbon dioxide and water. The oxidation was also studied in a static system with careful analysis of the reaction products.

The Nitration of Bicyclo (2,2,1) heptane. R. T. BLICKENSTAFF AND H. B. HASS. *Jour. Amer. Chem. Soc.* **68** (1946) p. 1431.

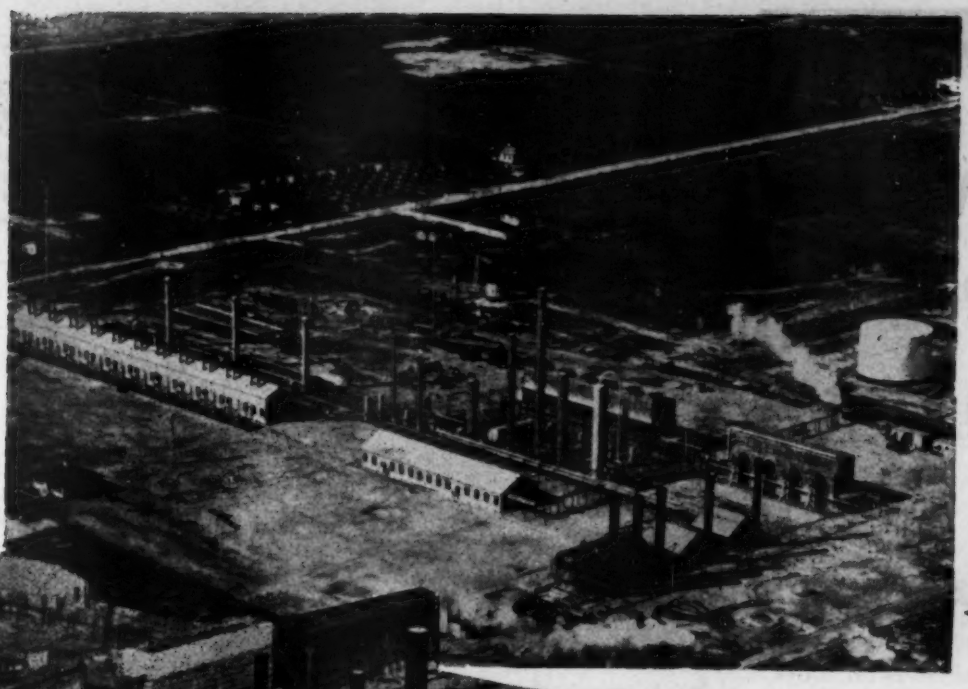
Bicyclo (2,2,1) heptane was treated with nitric acid in the vapor-phase in order to determine whether or not a bridgehead carbon atom would be nitrated under these conditions. The component was found to contain no primary or secondary nitro group, and was therefore 1-nitrobicyclo (2,2,1) heptane. The possibility of nitrating a bridgehead carbon atom was thus proved.

The Effects of Radioactivity on a Naphthenic Acid. I. A. BREGER AND V. L. BURTON. *Jour. Amer. Chem Soc.* **68** (1946) pp. 1639-42.

It has been suggested naturally-occurring naphthenic acids may be degradation products of sterols. Irradiation of a naphthenic acid by alpha particles and deuterons has led to its conversion into a naphthenic component of crude oils. Cyclohexane rings, and presumably the more stable cyclopentane rings, are not opened as a result of alpha particles or deuteron bombardment. The mechanism by means of which cyclohexanecarboxylic acid was transformed into cyclohexane and cyclohexane is unknown. Several possible processes for the transformation are suggested, as, for example: decarboxylation to cyclohexane followed by partial dehydrogenation to cyclohexane.

The Effects of Radioactivity on Fatty Acids. C. W. SHEPPARD AND V. L. BURTON. *Jour. Amer. Chem. Soc.* **68** (1946) pp. 1636-39.

The authors note that the origin of petroleum remains an unanswered scientific question. It has been suggested that a likely process for the formation of petroleum is the decomposition and conversion of the solid and semi-solid organic compounds in marine sediments by alpha radiation. To test the radio-activi-



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ty hypothesis, certain organic compounds likely to be found in source sediments have been bombarded by alpha particles from radon and its active deposit. Since the molecular weights of the fatty acids are not entirely certain, four acids of different molecular weights were bombarded in the experiments reported by the authors. These were acetic, caprylic, lauric and palmitic. Acetic acid was bombarded in the vapor state at 130° C., and the others in the solid state. In all cases the gas phase was analyzed after bombardment and the solid residues of aluric and palmitic acids were examined. Fatty acids can be decarboxylated by alpha-particle radiation to form hydrocarbons such as are found in petroleum. The mechanism of the process is briefly discussed.

Manufacture: Processes and Plant

Developments in Fluid Catalytic Cracking. J. F. WALTER. *Jour. Inst. Petr.* **32** (1946) pp. 295-312.

The author reviews the developments in fluid catalytic cracking during the war. In general, developments led to simplified design, reduction in cost, improvement in yield, and reduction in operating costs. Methods were developed for forming synthetic bead catalysts which were more easily recovered from gases and vapors and which suffered less loss by attrition. Three types of catalysts were used: natural, silica-alumina, and silica-magnesia. Fluid catalytic cracking is capable of operating at high temperatures, and for this reason permit production of light mono-olefins which should find use in chemical manufacture. Typical flowsheets are included, and typical yields and product qualities are tabulated for the application of the three catalysts mentioned. In the processing of Mid-Continent gasoil, the results of fluid catalytic cracking with silica alumina catalyst are compared with normal thermal cracking and severe thermal cracking from the standpoint of producing hydrocarbons for possible use in chemical synthesis.

Some Physical Properties of Activated Bauxite. H. HEINEMANN, K. A. KRIEGER, AND W. S. W. MCCARTER. *Ind. & Eng. Chem.* **38** (1946) pp. 839-42.

Thermally-activated bauxite is used for the adsorbent refining of lubricating oils and waxes, as a desiccant, as a catalyst support, as a catalyst for desulfurization, defluorination, cracking, dehydrogenation, and dehydration reactions. Data are given on the bulk, apparent and true densities, corresponding void and pore volumes, and surface areas and equivalent pore diameters of several bauxite ores activated at various temperatures. Bulk density and void volume depend upon granule size. The other physical properties are altered by changes in structure caused by increasing activation temperatures. It appears that bauxite granules posses a degree of rigidity sufficient to prevent collapse of the framework even under the action of forces associated with major chemical changes. The methods used in making the physical measurements are outlined. The physical properties of the adsorbents activated at different temperatures are tabulated. The relationship of the various properties to activation temperature is also depicted in graphical form. A bibliography of 21 references is included.

The Development of Improved Turbine Oils. C. N. SMITH AND G. H. S. SNYDER. *Jour. Inst. Petr.* **32** (1946) pp. 312-22.

Under average service conditions, high-quality, straight mineral turbine oils properly refined from selected crudes adequately meet the lubrication requirements of most steam turbines. Premium-quality straight mineral oils have given satisfactory service over periods as long as 25 years, and service periods of 10 years under average operating conditions are quite common. The lubrication of some turbines is more difficult than others, and for these so-called severe turbines it has been necessary to develop additive-type oils having oxidation resistance and rust-preventive properties not attainable with straight mineral oils. The oxidation testing of turbine oils is described including the Brown Boveri test, the ASTM Turbine Oil test, and Socony-Vacuum Field Service test. Rust-inhibiting characteristics are practically always determined by the ASTM procedure, making use of a polished steel rod. Field testing of turbine oils is described.

Products: Properties and Utilization

The Determination of Organic Peroxides in Hydrocarbons. E. M. TANNER AND T. F. BROWN. *Jour. Inst. Petr.* **32** (1946) pp. 341-50.

The authors were concerned with the determination of organic peroxides in hydrocarbon oils, and accordingly tried several methods presented in the literature. The results obtained by the use of these methods were very low. Known amounts of different peroxides were added to straight-run gasoils. A method especially suitable for the determination of peroxides in hydrocarbon oils was developed. This was based on the reduction of the peroxide by ferrous ammonium sulphate in an inert atmosphere and subsequent titration of the excess ferrous salt with standard potassium dichromate solution. The method also has been extended to the determination of peroxides formed in cracked gasolines. The effect of the variables of the procedure was studied and is described. A bibliography of 13 references is included.

Mineral Oil Films in Relation to Mosquito Control. A. CROSSFIELD AND G. F. HAZZARD. *Jour. Inst. Petr.* **32** (1946) pp. 323-40.

The control of mosquito larvae by means of oil spraying has been practised for many years, but the application of fundamental principles to the manufacture of oils of suitable characteristics with respect to the formation of con-

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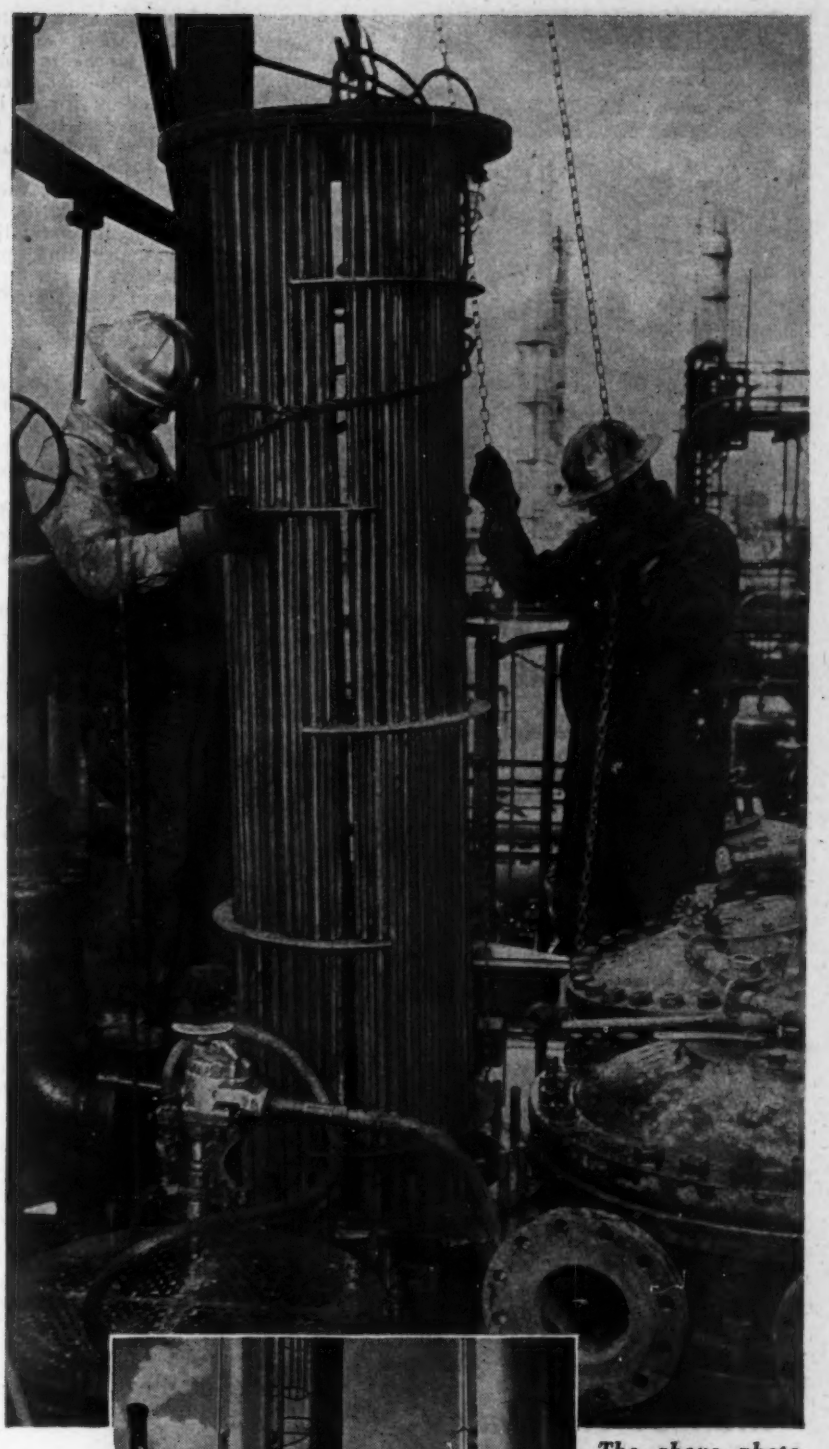

The above photograph shows installation of tube bundle equipped with Anaconda Condenser Tubes at the Houston, Texas refinery of Shell Oil Company. At left is view of one of refinery units.

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tinuous mineral-oil films on water surfaces is quite recent. A mosquito larvicide should kill all larvae in the areas treated, and have a residual effect preventing further breeding for as long as possible. It should not be toxic to man or animals. An oil of low viscosity is desirable for rapid penetration of the tracheae of larvae. However, the lower the viscosity the more volatile the oil, and thus the less the film stability and durability. The spreading pressure should be high in order to produce more complete spread over contaminated surfaces and also films more stable to wind and mechanical displacement under field conditions. Use of a highly aromatic oil or a cracked material such as pressure-distillate bottoms, gives a highly toxic oil. However, the film stability of aromatic fractions is poor, and with pressure-distillate bottoms rapid oxidation and polymerization may occur in the field to give incomplete films. In general, field experience has not correlated too well with film stability tests in the laboratory.

Evaluation of Unsaturation in Mixtures of Hydrocarbons (Motor Gasoline) by the Use of Pyridine Sulfate Bromide. G. E. WILSON AND H. B. NISBET. *Analyst* **71** (1946) pp. 183-4.

The modified procedure described has proved superior to the much-used method of McIlheney. In this latter method, error is introduced in determining unsaturation by consumption of some of the bromine in substitution reactions. Pyridine sulfate dibromide is easily prepared. When used as the brominating agent, the danger of forming bromine substitution compounds is eliminated and excellent results are therefore obtained. Directions are given for making the determination.

Detection of Elemental Sulfur in Gasoline by the Sommer Test. G. E. MAPSTONE. *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 498-99.

In testing for sulfur in gasoline the mercury test is by far the most sensitive, being positive even below 0.1 p.p.m. The inverted doctor test, using butyl mercaptan, is positive to 15 p.p.m. of free sulfur, but the color of the lead mercaptide tends to make detection difficult near the limiting concentration. The Sommer test is sensitive to 3 p.p.m., and is therefore about five times as sensitive as the inverted doctor test, and yet not too sensitive for plant control. The procedure to be followed is described in some detail.

Molecular Weight and Mercaptan Content of Mixtures of Primary Mercaptans. H. A. LAITINEN, A. S. O'BRIEN, AND J. S. NELSON. *Ind. & Eng. Chem., Anal. Ed.* **18** (1946) pp. 471-2.

Commercial mercaptans may contain varying quantities of alkyl disulfides, alkyl halides, alcohols, and other substances as impurities. A method was desired for determining the average molecular weight of the mercaptan fraction rather than the average molecular weight of the whole sample. The mercaptan sulfur content of a solution of primary mercaptans is determined by titration with silver nitrate, and the weight of silver mercaptide formed during the titration was determined. From these data the average molecular weight of the mercaptans and the percentage of mercaptans can be calculated.

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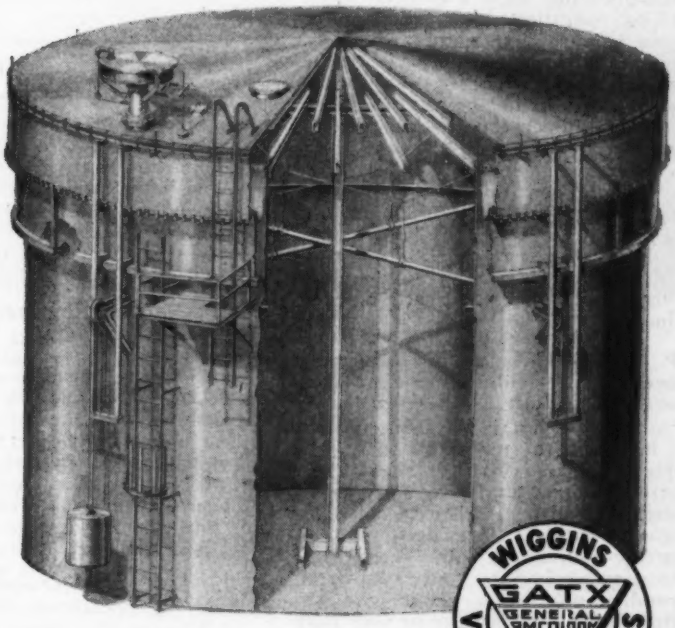

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CRACKING AND REFORMING

U.S.P. 2,403,486. Combination Catalytic and Thermal Conversion. J. M. Barron to The Texas Company.

In the combination thermal and catalytic cracking of hydrocarbon oils for the unitary processing of a charging stock obtained from crude petroleum and containing both residual and gasoil components thereof, the process that comprises introducing said charging stock to a reaction chamber, passing lower-boiling hydrocarbons through a heating zone wherein they are heated to a cracking temperature, directing the resultant heated products to said reaction chamber to subject the residual stock to cracking and vaporization therein, passing separated vapors from the reaction chamber to a catalytic-cracking zone wherein such fractions are subjected to catalytic cracking, withdrawing residual products from the reaction chamber and subjecting them to coking, fractionating vapors evolved from the coking operation to separate lighter fractions from higher-boiling fractions, directing said lighter fractions to the aforesaid heating zone for conversion, subjecting said higher-boiling fractions to cracking temperature with sufficient time of reaction to effect extensive thermal conversion including the cracking of olefins and paraffins, subjecting the resultant thermally-cracked products of reduced paraffinicity to catalytic cracking and fractionating the products produced in the catalytic-cracking operations to recover the catalytically-cracked gasoline.

U.S.P. 2,403,929. Catalytic Reforming Process. C. S. Kuhn to Socony-Vacuum Oil Company.

A mixture of an isoparaffin and an olefin in which the molar ration of isoparaffin to olefin is greater than 2:1 is contacted under suitable conditions of temperature and pressure with a hydrofluoric acid catalyst, forming a relatively narrow-boiling alkylate. Enough of the isoparaffin is then separated from the product mixture to reduce the isoparaffin-alkylate mol ratio to less than 1:1. The alkylate product mixture is again contacted with a hydrofluoric acid catalyst, in order to reform the alkylate to higher- and lower-boiling saturated hydrocarbons; the reaction is continued until a mixture of hydrocarbons is obtained, the boiling range of which has a desired distribution over the gasoline boiling range. This fraction is recovered and the saturated hydrocarbons boiling below and above the desired range are returned to the alkylating step.

U.S.P. 2,404,452. Production of Aviation Gasoline. I. G. Nixon to Shell Development Company.

Straight-run naphtha boiling between 90 and 230° C. is non-catalytically cracked. A second naphtha fraction boiling within the same range is separated from the cracked product and recracked under similar conditions. A heavy fraction boiling between 140 and 230° C. and separated from the second cracking product is subjected to further non-catalytic cracking. An aviation base stock boiling between 100 and 200° C. is thus obtained. All the cracking operations are carried out at 540-580° C., and under 40-100 kg. per cm.^{2} pressure.

U.S.P. 2,404,595. Catalytic Conversion of Hydrocarbon Oils. C. Richker and du-Bois Eastman to The Texas Company.

A relatively clean gasoil of good color is thermally cracked at 900-1050° F. to produce 8-10 volume percent of gasoline. The vapors containing the gasoline hydrocarbons are passed through a stationary bed of active cracking catalyst at a liquid space velocity of 3-10 and at 900-1050° F. The catalytically-cracked gasoline amounts to about 10 percent by volume of the gasoil. After about 5-20 percent by weight of carbon has formed on the catalyst, the catalyst is regenerated.

ISOMERIZATION

U.S.P. 2,403,649. Hydrocarbon Reconstruction. F. E. Frey to Phillips Petroleum Company.

The isomerization of a normal paraffin having at least 4 C atoms is carried out at 50-1000° F. in the presence of 0.2-4 times its weight of concentrated hydrofluoric acid as effective catalyst.

U.S.P. 2,403,650. Reconstruction of Paraffins. F. E. Frey to Phillips Petroleum Company.

Low-boiling paraffins of at least 4 C atoms are isomerized in vapor phase at 250-1000° F. in the presence of 0.1-4 times their weight of HF acid. A heavy oil is passed through the reaction zone to absorb reaction products of high molecular weight and minimize carbon and tar formation. Separation of products is carried out by fractional cooling.

U.S.P. 2,403,671. Isomerization of Olefinic Hydrocarbons. M. P. Matuszak to Phillips Petroleum Company.

Olefins, diolefins and other unsaturated compounds can be isomerized in the presence of catalysts suitable for the dehydrogenation of hydrocarbons such as "black" chromium oxide. Temperatures below those at which the catalysts are active in dehydrogenation are used, such as 150-350° C. No significant change occurs in the carbon skeleton of the organic compound.

U.S.P. 2,403,757. Process for Isomerizing Dialkyl Benzenes. E. D. Reeves to Standard Oil Development Company.

A feed stock of ortho substituted dialkyl benzenes is isomerized to para and meta isomers by contact at 500-1100° F. with a synthetic silica-alumina catalyst containing at least one oxide taken from the group consisting of boron oxide, thoria, sirconia and magnesia. A space velocity of 0.6-4 liquid volumes of feed per volume of catalyst per hour is maintained.

U.S.P. 2,403,811. Isomerization of Hydrocarbons. J. W. Loy to Phillips Petroleum Company.

The isomerization of paraffin hydrocarbons is carried out in the presence of an aluminum halide catalyst using a solvent for the aluminum halide and performing the reaction under reflux of hydrocarbons or solvent or both, thus providing a vapor-liquid interchange in the reaction zone and returning vaporized aluminum halide to the liquid reaction mixture. SO_2 is a preferred solvent.

U.S.P. 2,404,080. Catalytic Conversion Process. T. B. McCulloch to Standard Oil Development Company.

Normal paraffins are isomerized by contacting them with sulfuric acid at 300-500° F. The isoparaffins obtained can be alkylated using the sulfuric acid from the isomerization step as the alkylation catalyst, after cooling it to alkylation temperature.

U.S.P. 2,404,436. Isomerizing Hydrocarbons. C. C. Crawford and D. L. Yabroff to Shell Development Company.

Isomerizable saturated hydrocarbons with at least 5 C atoms, such as methylpentane are admixed with hydrogen halide and contacted under isomerizing conditions with uncombined aluminum chloride in the absence of any added free metal. In order to avoid hydrocarbon decomposition small amounts (of not more than 1 percent of the treated hydrocarbon) of uncombined hydroquinone are introduced into the reaction zone.

U.S.P. 2,404,444. Isomerization Process Using Metal Halide Complexes. C. A. Kraus and J. D. Calfoe to Sandard Oil Development Company.

Normal paraffins with at least 4 C atoms, such as butane or heptane, are contacted under isomerization conditions and in the presence of a halogen-containing promoter with a catalyst prepared by admixing a metal halide of the Friedel-Crafts type with an alkoxy derivative of an aluminum halide, such as methoxy aluminum chloride, and heating the resultant mass to remove metal halide.

U.S.P. 2,404,483. Production of Motor Fuel Hydrocarbons. F. E. Frey to Phillips Petroleum Company.

A low-boiling normal paraffin (having preferably at least 4 C atoms) is subjected to catalytic conversion in the presence of HF. An isoparaffin, primarily isobutane, and a volatile normally liquid hydrocarbon fraction boiling in the motor fuel range are obtained. The isoparaffin fraction is alkylated with an alkylating reactant, such as butenes in the presence of the HF to produce higher isoparaffin in the motor fuel

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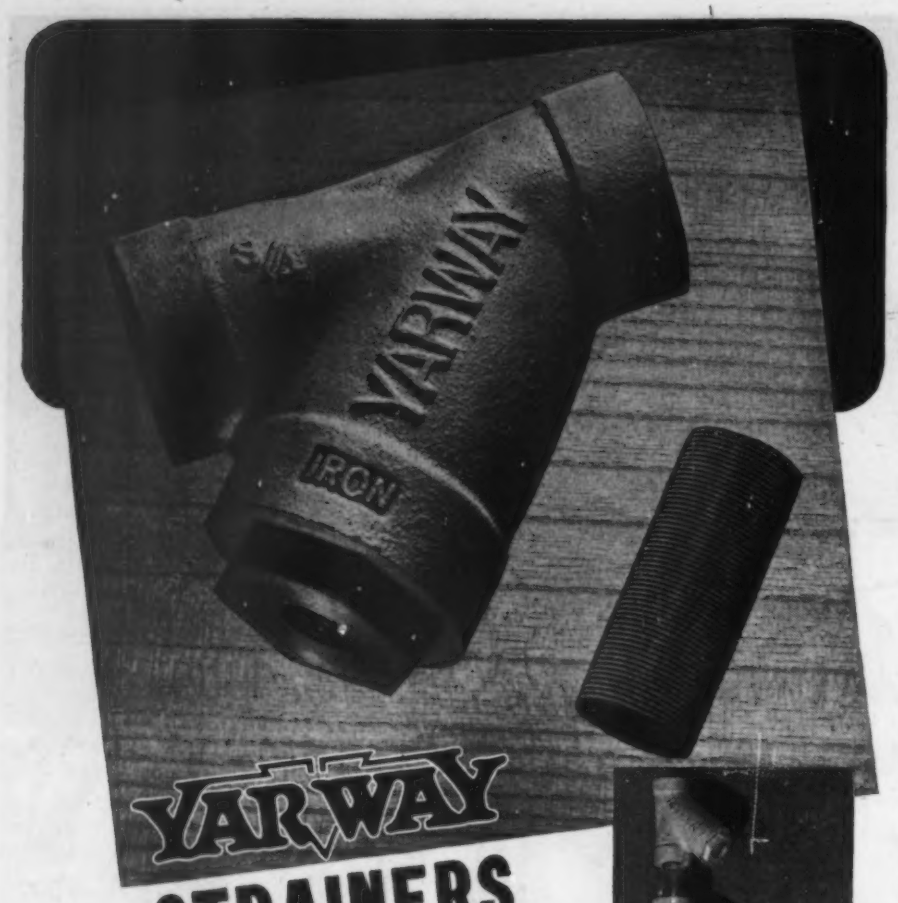

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range. The two hydrocarbon fractions may be blended.

U.S.P. 2,404,499. Isomerization of Hydrocarbons. J. O. Iverson to Universal Oil Products Company.

Paraffinic hydrocarbons, such as n-butane, are isomerized by passing the heated hydrocarbons together with a hydrogen halide through a stationary bed of granular metal halide such as Al_2Cl_6, under isomerizing conditions. Another portion of the paraffinic hydrocarbons is introduced to at least one intermediate point of the catalyst bed to inhibit an undue temperature rise of the bed. The reaction products are passed through a solid, preferably granular adsorbent material for the removal of metal halide contained in the product while introducing an additional portion of the paraffinic hydrocarbons to at least one intermediate point of the body of this adsorbent material. The isomerized hydrocarbons are recovered by fractionation.

U.S.P. 2,404,591. Preparation of Aromatic Hydrocarbons from Hydrocarbon Mixtures. E. A. Naragon to The Texas Company.

An aromatic concentrate boiling between 212-300° F. and separated from hydroformed naphtha which has a blending I.M.E.P. of about 170 is isomerized in the presence of a catalyst and a hydrogen halide promoter at 180-220° F. to a product having a blending value of 230. The catalyst is an aluminum halide-hydrocarbon complex, prepared by reacting $AlCl_3$ and kerosine in the presence of HCl at 200-250° F. so as to produce a complex having a heat of hydrolysis of 290-330 cal./g. of complex.

U.S.P. 2,404,649. Isomerizing Hydrocarbons. M. Neuhaus to The Texas Company.

Feed hydrocarbon such as n-pentane is continuously introduced to the lower portion of a packed tower while a stream of catalyst such as an aluminum halide-hydrocarbon complex is continuously introduced to the upper portion of the tower. Under operating conditions substantial vaporization of hydrocarbons occurs, causing countercurrent flow. A suitable isomerization promoter such as a hydrogen halide is present. The operation involves simultaneous isomerization of the feed hydrocarbon and fractionation between reacted and unreacted hydrocarbons. The hydrocarbons in passing through the tower are subjected to repeated alternate vaporization and condensation.

U.S.P. 2,404,661. Manufacture of Motor Fuel. R. T. Sanderson to The Texas Company.

A mixture comprising 2,2,3-trimethylbutane and its isomer 2,4-dimethylpentane is treated with concentrated sulfuric acid at 70-125° F. 2,4-dimethylpentane undergoes conversion to 2,3-dimethylpentane. After neutralizing with alkali, the mixture is fractionated to separate the 2,2,3-trimethylbutane.

U.S.P. 2,404,923. Isomerization of Butane. R. J. Patterson to Phillips Petroleum Company.

N-butane is isomerized in contact with an $AlCl_3$ catalyst and a HCl promoter. The vaporous effluent is cooled and condensed and fractionated into an overhead fraction containing HCl, propane and lighter hydrocarbons and a butane bottom fraction. The overhead fraction is liquified and fractionally distilled into an overhead of HCl and lighter than C

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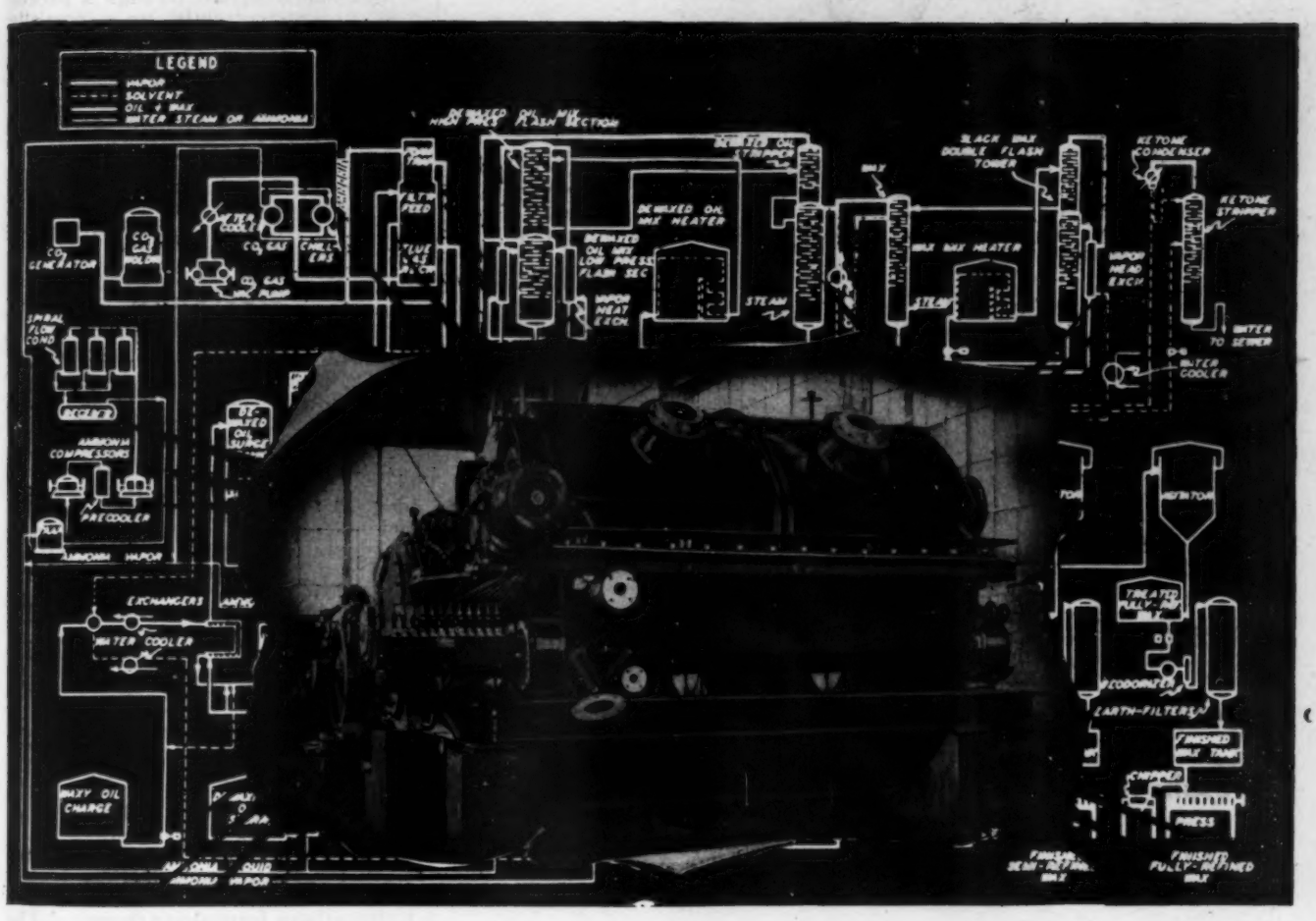

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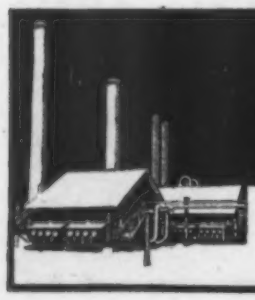

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hydrocarbons which is recycled to the isomerization zone and a propane bottoms fraction which is employed as reflux in the first distillation zone.

U.S.P. 2,405,097. Process for Nondestructive Hydrocarbon Conversion. F. C. Neuhart to Phillips Petroleum Company.

N-butane is passed through a packed tower countercurrently to a partially deactivated $AlCl_3$ sludge under conditions to effect a preliminary isomerization. The gaseous hydrocarbon mixture is then passed into the bottom of a reactor the upper portion of which contains solid $AlCl_3$. The gases flowing upwardly are first contacted with fresh $AlCl_3$ under isomerization conditions. Fresh sludge is formed in the upper part of the reactor, passed downward and to the preliminary treating zone.

ALKYLATION

U.S.P. 2,403,785. Alkylation Method. E. C. Britton and J. C. Vander Weele to The Dow Chemical Company.

By carrying out the reaction between an olefin and a benzene compound, e.g., a hydrocarbon or neuclear halogenated hydrocarbon of the benzene series at a temperature above 90° and below 200° C. and under a pressure sufficient to liquefy the mixture, the proportion of catalyst required for the reaction may be greatly reduced and higher yields of mono alkylated relative to poly alkylated hydrocarbons are formed. $AlCl_3$ is employed as a catalyst in amounts of 0.00175-0.007 mol equivalents per mol of aromatic compound.

U.S.P. 2,403,922. Catalytic Hydrocarbon Reactions. W. P. Hawthorne to Socony-Vacuum Oil Company.

A feed stock containing isoparaffins and olefins in the vapor phase is introduced to liquid hydrogen fluoride under such conditions that the products of the reaction are predominantly liquid while the reactants are vaporous. The liquid hydrocarbons formed are recovered. The charge mixture containing isoparaffin and olefin is prepared in the liquid phase, vaporized and expanded in indirect heat exchange with the liquid hydrogen fluoride to cool the reaction zone. Unreacted vaporous hydrocarbons are withdrawn from the reaction zone and recycled after admixture with the vaporized charge mixture. A mixture of isobutane and butene is preferably used for the feed stock.

U.S.P. 2,403,930. Alkylation Process. C. S. Kuhn to Socony-Vacuum Oil Company.

Isoparaffins are alkylated with ethylene in the presence of hydrofluoric acid of at least 90 percent concentration and a metal salt of an inorganic acid whose standard free energy of reduction to metal and non-aqueous acid is less than about 8000 calories per gram equivalent of free acid reduction product. The salts do not form stable double salts with the acid catalyst and are the salts of a metal below hydrogen in the electromotive force series. Salts of mercury and silver are preferred.

U.S.P. 2,403,931. Catalytic Alkylation Process. C. S. Kuhn to Socony-Vacuum Oil Company.

The alkylation of isoparaffins with ethylene is carried out by means of a catalyst which comprises concentrated sulfuric acid and mercury or silver cyanide. The salts are present in amounts

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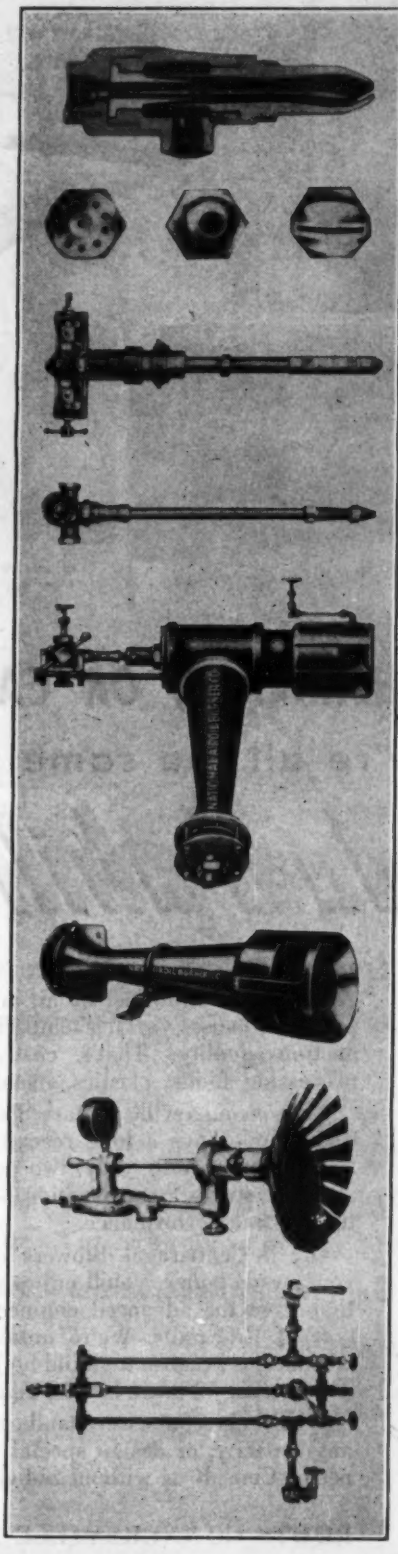

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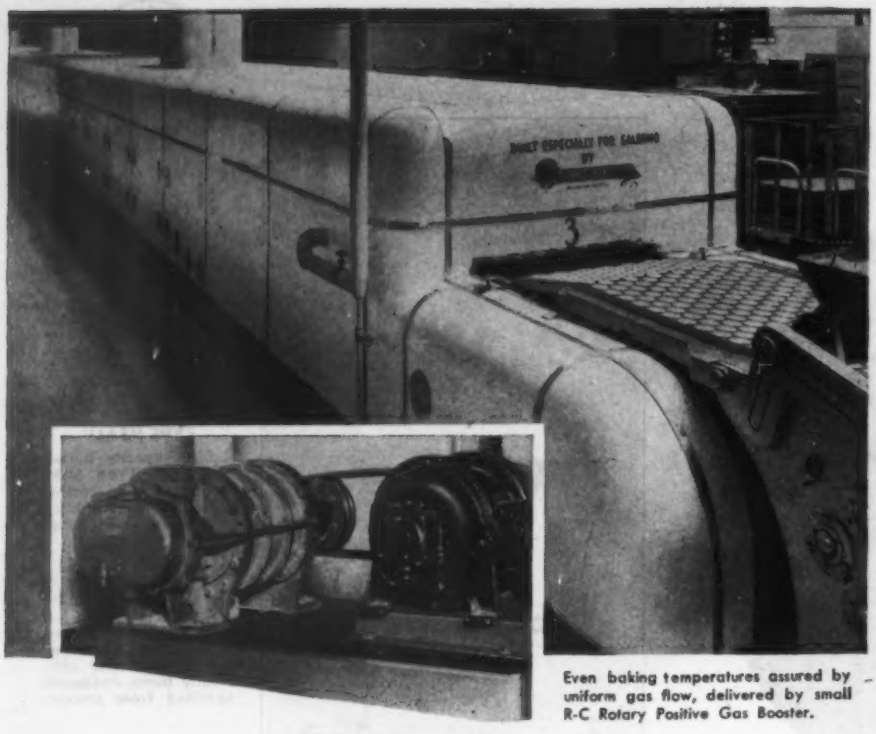

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of 0.2-2 percent and a reaction temperature of —10 to 60° C. is employed.

U.S.P. 2,404,050. Production of Motor Fuels. G. R. Gilbert to Standard Oil Development Company.

Products of the alkylation of isoparaffins with olefins are converted into materials of higher octane number and materials of a less saturated nature by reforming an alkylate fraction boiling above 300° F. at temperatures from 750-1100° F. and under pressures from 100-600 psi for a time sufficient for the conversion of not more than 30 percent of the charge to a product of lower molecular weight and boiling point than the charge. The products are separated by distillation.

U.S.P. 2,404,100. Alkylation of Naphthenes. L. Schmerling to Universal Oil Products Company.

A naphthenic hydrocarbon is treated with an alkyl halide in the presence of a catalyst formed by adding an aluminum halide to a nitroparaffin, preferably at 0-100° C. High-molecular-weight alkylated hydrocarbons are obtained.

U.S.P. 2,404,120. Production of Aromatic Derivatives. W. N. Axe to Phillips Petroleum Company.

An aromatic compound is reacted with a normal 1,3-diolefin in the presence of a catalyst obtained by saturating water with boron trihalide to produce normal aliphatic derivatives of aromatic compounds, such as alkyl benzene. The aromatic compound is preferably used in molar excess.

U.S.P. 2,404,340. Production of High Antiknock Fuel. G. B. Zimmerman to Universal Oil Products Company.

Propylene is polymerized and at least a portion of the polymers is subjected to the action of an olefin isomerizing catalyst. An alykylatable hydrocarbon is then alkylated with at least a portion of the isomerized propylene polymer. For example, iso-butane may be alkylated with the isomerized polymer of propylene in the presence of a hydrogen fluoride catalyst to form a high-octane-number gasoline.

U.S.P. 2,404,393. Alkylation of Paraffin Hydrocarbons. H. C. Mayland to Universal Oil Products Company.

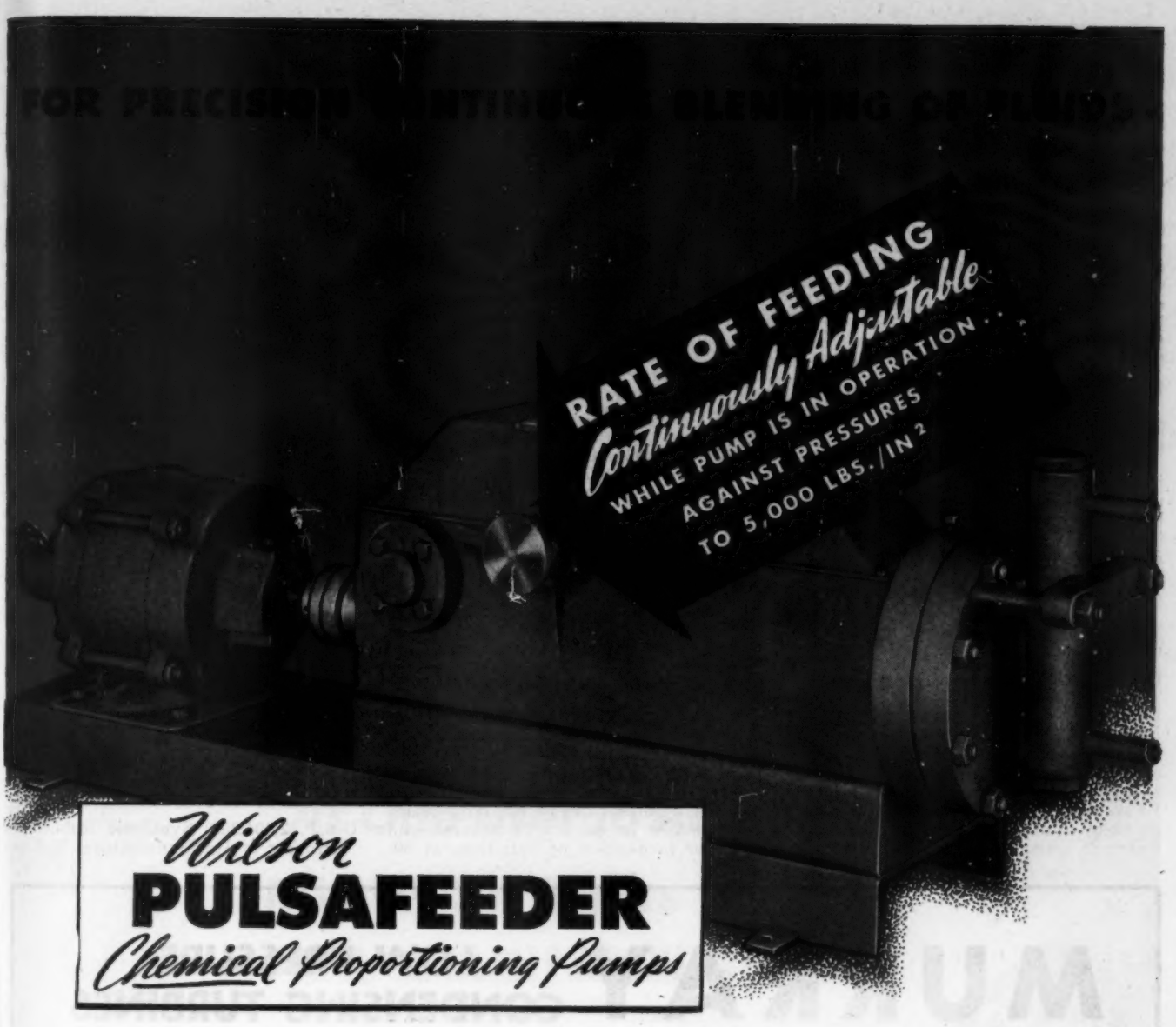
An isoparaffin, such as isobutane, is reacted with an olefin, for example a normally gaseous one, in the presence of anhydrous HF. The catalyst phase thus formed contains an organic diluent of higher molecular weight than the alkylated isoparaffin. The accumulation of this organic diluent in the catalyst phase is controlled to maintain the HF concentration within the range of 70-85 percent by weight. This control is carried out by withdrawing used catalyst from and adding more concentrated HF to the alkylating step in a regulated manner.

U.S.P. 2,404,498. Production of Toluene. V. N. Ipatieff and G. S. Monroe to Universal Oil Products Company.

To produce toluene, a mixture of benzene and methane is contacted with a metal or an oxide of a metal of atomic number 26-29, such as iron or iron oxide, at 275-450° C. under a pressure of about 10-450 atmospheres.

U.S.P. 2,404,536. Alkylation of Hydrocarbons. L. Schmerling to Universal Oil Products Company.

An aromatic hydrocarbon is reacted with a compound capable of yielding an alkyl radical, such as an olefin, in the presence of a catalytic compound of the general formula $RCOOMX_n$, wherein R



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No need to stop the system, or the pump, for adjustment, minor or major, of rate of flow with the Wilson Pulsafeeder. Hand wheel provides micrometer adjustment of rate—from zero to full maximum. Models available for feeding up to 800 gallons per hour. Hydraulically-balanced diaphragm head isolates pump from fluid being handled, protects fluids from contamination. Box construction provides oil-bath lubrication for all moving parts except motor, gives positive lubrication to assure low maintenance and long life. Write for description and specifications. *Process Equipment Division, Lapp Insulator Co., Inc., 160 Maple Street, LeRoy, N. Y.*

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WILSON PULSAFEEDER CHEMICAL PROPORTIONING PUMPS

is an alkyl group, X a halogen, n an integer less than 4, and M a metal capable of forming a metal halide of the Friedel-Crafts type, e.g., the compound $CH_3COOAlCl_2$.

U.S.P. 2,404,537. Treatment of Hydrocarbons. L. Schmerling to Universal Oil Products Company.

For synthesizing hydrocarbons, an isoparaffinic hydrocarbon such as iso-butane is reacted with an alkyl chloroformate, such as ethyl chloroformate, under alkylating conditions in the presence of a Friedel-Crafts type metal halide. A temperature of about —20 to 100° C. and a pressure of from atmospheric to 50 atmospheres may be employed.

U.S.P. 2,404,607. Product of Alkylation Reagent and Alkylation Process. P. L. Veltman and L. W. Devaney to The Texas Company.

Isopropyl iodide and zinc are brought in contact in the presence of an inert, non-aromatic hydrocarbon liquid. A solution containing isopropyl zinc iodide is formed which is an excellent reagent for reaction with an alkyl halide such as tertiary butyl chloride. Isopropyl iodide and zinc are reacted at 50-75° C. The alkyl halide is added at about 0° C. Triptane is produced from tertiary butyl chloride.

U.S.P. 2,404,897. Alkylation Process. W. N. Axe to Phillips Petroleum Company.

Low-boiling isoparaffins and olefins such as i-butane and ethylene in a 3:1 molar ratio are alkylated at 100-106° F. and under 250 psi pressure with a liquid BF_3-orthophosphoric acid catalyst, prepared by diluting phospholeum with sufficient 85 percent phosphoric acid to give 100 percent phosphoric acid which is saturated with anhydrous BF_3.

U.S.P. 2,404,927. Manufacture of Isoparaffins. L. Schmerling and V. N. Ipatieff to Universal Oil Products Company.

Highly branched isoparaffins are formed by reacting a mono olefin with an alkyl halide in the presence of a Friedel-Crafts type catalyst such as $FeCl_3$ at —10 to 125° C. The product is dehydrohalongenated in the presence of an alkaline catalyst such as soda lime at 200-450° C. to produce a mixture of olefins which are reacted with hydrogen halide at —50 to 50° C. to produce isomerized higher-molecular-weight alkyl halides. Methyl groups are then substituted for the halogen atoms by reacting with methyl magnesium chloride or zinc dimethyl.

U.S.P. 2,404,934. Conversion of Hydrocarbons. R. B. Thompson to Universal Oil Products Company.

Isobutane-ethylene alkylation products boiling above about 65° C. are reacted with isobutane in the presence of a liquid $AlCl_3$-hydrocarbon complex and HCl to produce lower-boiling hydrocarbons comprising 2,3-dimethyl butane. The reaction is carried out at 10-100° C. in the liquid phase.

POLYMERIZATION AND CONVERSION

U.S.P. 2,403,963. Alkenylation Process. W. N. Axe to Phillips Petroleum Company.

Phenyl butene is produced by reacting a major proportion of benzene and a minor proportion of butadiene at 50-150° F. in the presence of a complex obtained by reacting boron fluoride with 1-1.5 mol equivalents of water.

U.S.P. 2,403,966. Polymer Slurry Process. J. R. Brown and I. E. Lightbown to Standard Oil Development Company.

A major quantity of an iso-olefin of 4-8 C atoms is polymerized with a minor quantity of a diolefin of 4-12 C atoms at —20 to —160° C. by means of a Friedel-Crafts type catalyst dissolved in a non-complex-forming solvent, such as an alkyl halide, which is liquid at the polymerization temperature. An inert deflocculating agent is added to the hydrocarbon feed. The polymers produced are separated in dispersed form and slurried in water.

U.S.P. 2,404,056. Manufacture of Isoprene. E. Gorin and A. G. Oblad to Socony-Vacuum Oil Company.

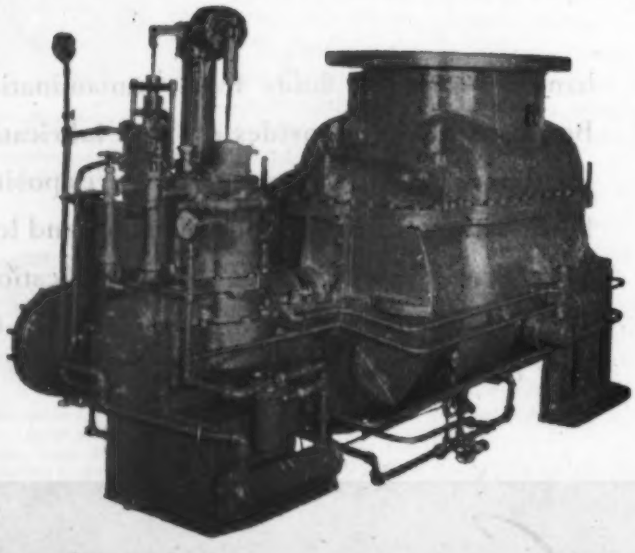
Propylene is dimerized in the presence of an alumina-silica catalyst. The polymerized product is fractionated to obtain a cut boiling from 60-70° C. This cut is pyrolized and the product is fractionated to recover pure isoprene.

U.S.P. 2,404,280. Production of Unsaturated Nitriles. H. A. Dutcher to Phillips Petroleum Company.

Unsaturated nitriles, such as acrylonitrile, are produced by passing the vapors of an aliphatic saturated aldehyde oxime, such as propionaldehyde oxime, over a dehydrating-dehydrogenating catalyst composed of aluminum oxide, e.g., bauxite, and a minor proportion of an oxide of chromium, molybdenum, vanadium or tungsten at 700-1100° F.

U.S.P. 2,404,392. Synthetic Rubber and Process of Its Manufacture. A. Maxi-

MURRAY LOW PRESSURE CONDENSING TURBINES



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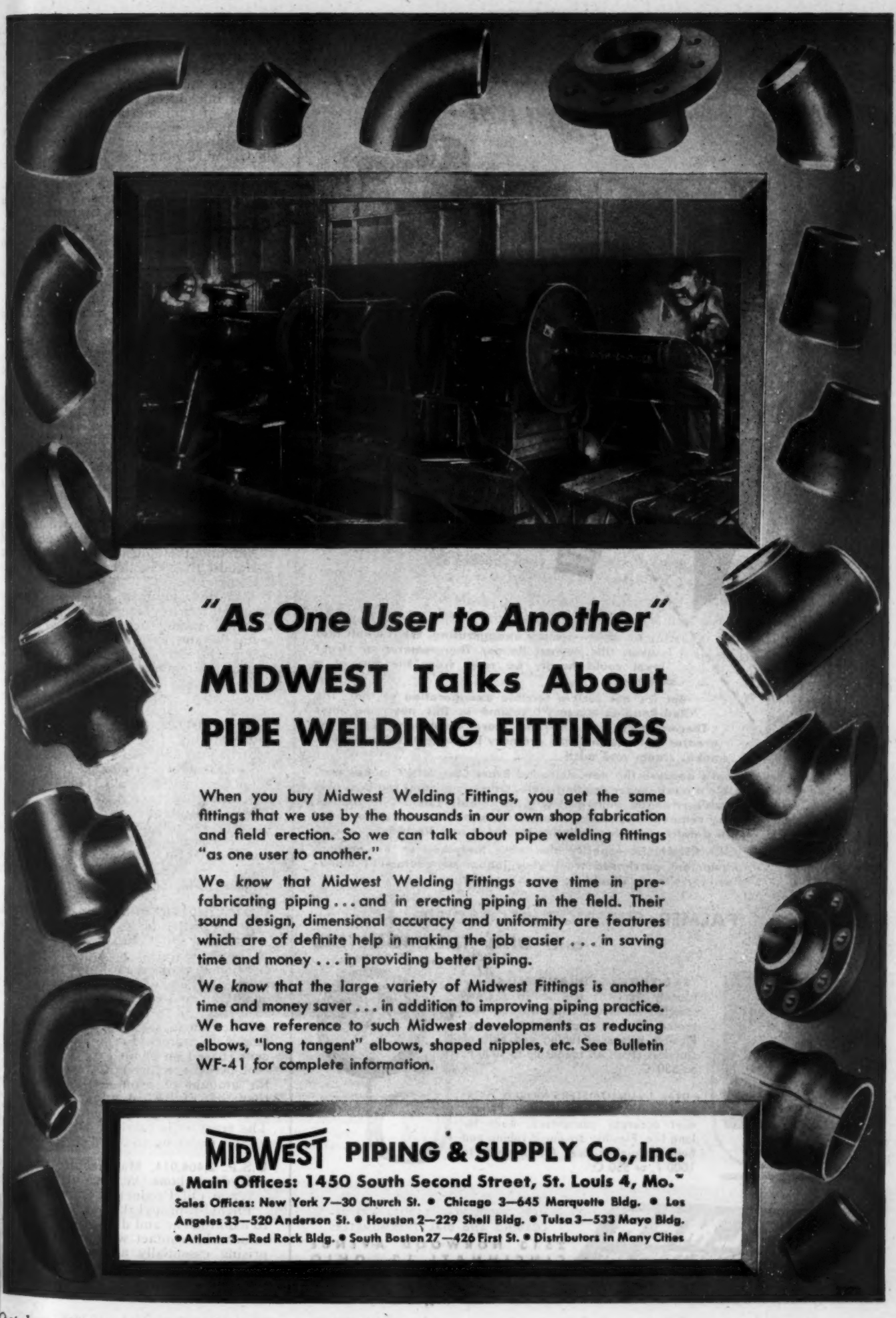

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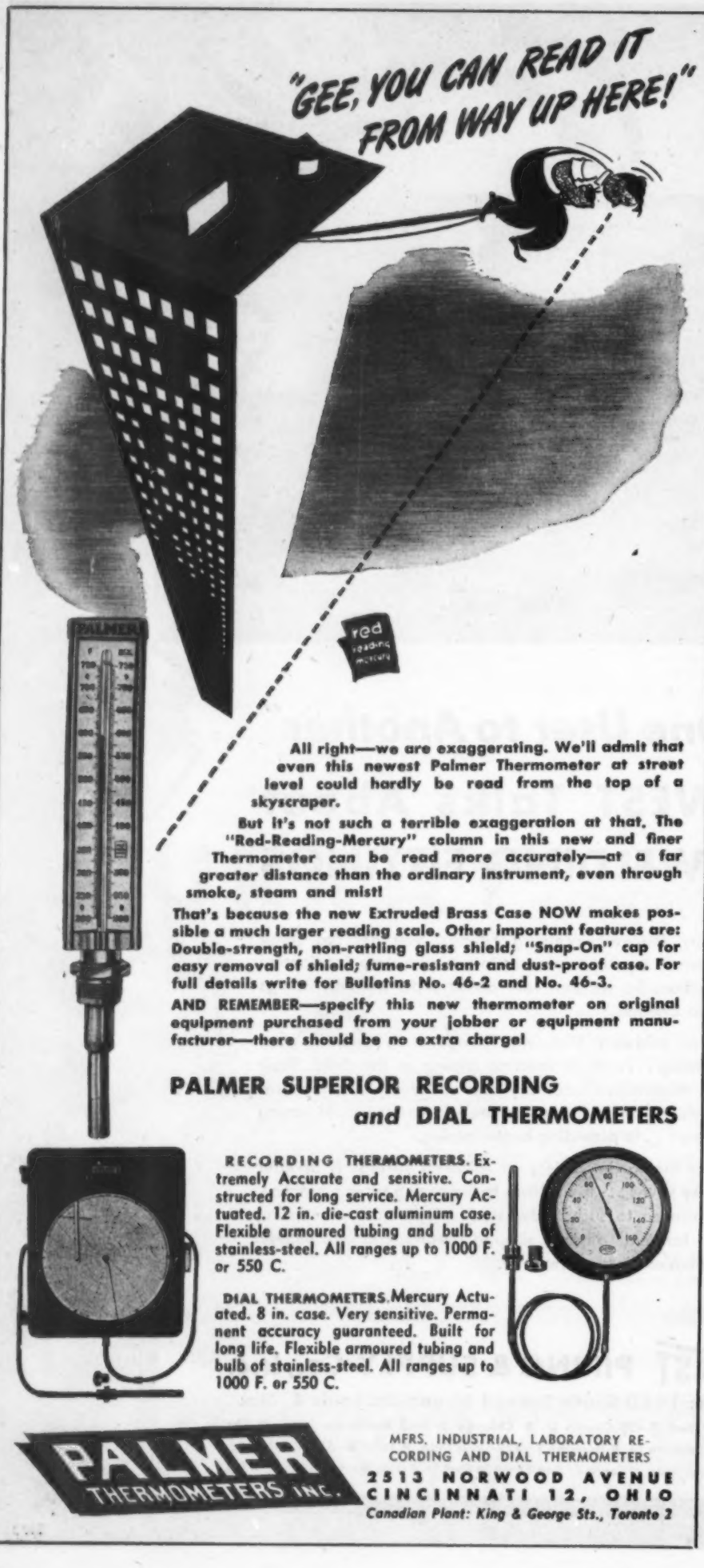

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1,3-butadiene is polymerized with vinylacetylene while kept in a state of emulsion. Thus, for instance a solution of butadiene and vinylacetylene in oleic acid is introduced into a solution of a mixture of ammonia and hydrogen peroxide under suitable pressure, and the dispersion formed is polymerized at 50-60° C. for 72 hours.

U.S.P. 2,404,438. Process for the Manufacture of Olefin Oxides. T. W. Evans to Shell Development Company.

An olefin oxide, such as ethylene oxide, is produced by reacting the olefin with oxygen in the presence of silver metal, activated by 0.5-5 percent of sodium or lithium salts of aliphatic carboxylic acids, such as formates or oxalates. The oxidation may be carried out at 150-500° C.

U.S.P. 2,404,538. Manufacture of Arylalkane Hydrocarbons. L. Schmerling to Universal Oil Products Company.

An aralkyl halide, such as 1-chloro-2-methypl - 2 - phenyl - propane is heated with an aqueous solution of a mineral acid or an acidacting inorganic salt of less than 5 percent concentration. An arylalkene, such as phenyl butene, is obtained. A temperature of 150-350° C. is preferably employed.

U.S.P. 2,404,599. Synthesis of Paraffinic Hydrocarbons by Reacting an Alkyl Aluminum Halide With an Aliphatic Halide. R. T. Sanderson to The Texas Company.

A methyl aluminum chloride, bromide or iodide can be reacted efficiently with an alkyl halide such as 2-chloro-2,3-dimethylbutane to produce triptane. The reaction is carried out at 0-50° C. The methyl aluminum chloride is prepared from duralumin, a small amount of iodine, methyl iodide and methyl chloride.

U.S.P. 2,404,628. Polymerization of Hydrocarbons. J. D. Grenko and L. R. Strawn to The Texas Company.

Propylene is polymerized to a naphtha containing 40-50 percent by weight of aromatics by contact at 580-650° F. under 100-300 psi pressure with a calcined mixture of precipitated silica, alumina and zirconia of the approximate composition 100 SiO_2 :2 Al_2O_3 : 12 ZrO_2. The catalyst is activated in a propylene stream at 425-560° F.

U.S.P. 2,404,788. Polymerizing Olefins. R. E. Burk and E. C. Hughes to The Standard Oil Company (Ohio).

The polymerization of olefins is carried out in the presence of BF_3 as a catalyst and an oxygen-containing compound of an element of atomic number 13, 14 and 22-28 as promoter. Aluminum silicates such as active clays are preferred promoters. From 0.2-25 mol percent (based on olefin) of BF_3 and 0.05-5 mol percent of promoter are employed, the amount of promoter being smaller than that of BF_3. A minor amount of a salt of a strong acid may be present. The reaction is carried out at about 80° F. and under up to 300 psi pressure.

U.S.P. 2,404,914. Manufacture of Cyclic Hydrocarbons. W. J. Mattox to Universal Oil Products Company.

Phenyl-n-propyl ketone is converted to naphthalene and di-n-propyl ketone to toluene by contact with a catalyst comprising essentially an oxide of an element selected from the left-hand columns of groups IV, V and VI of the periodic table. Reaction temperatures

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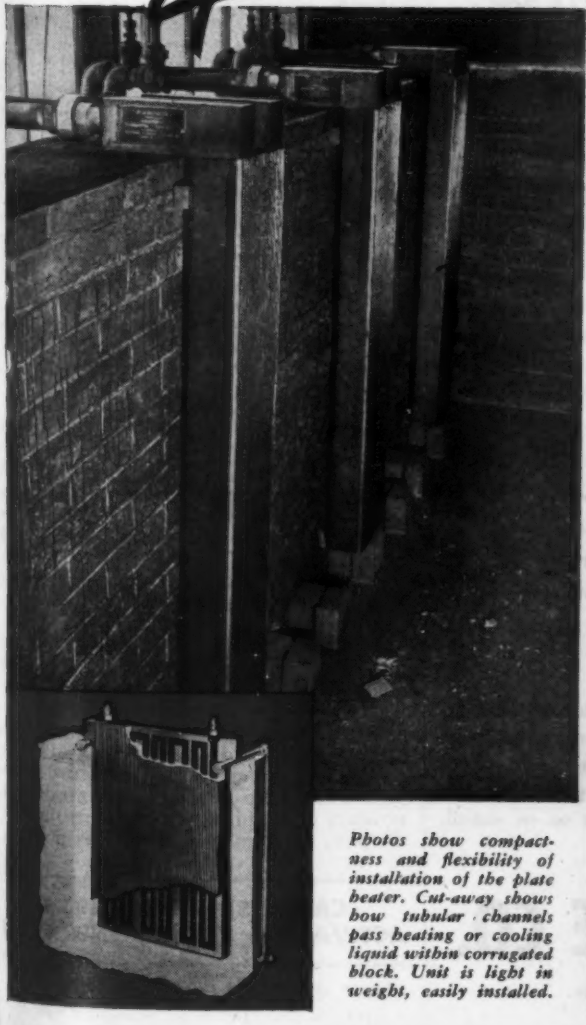

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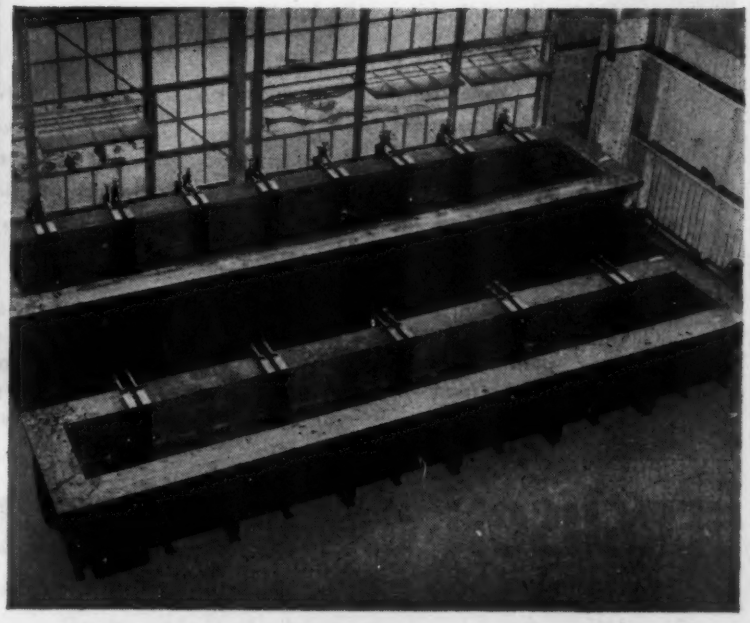

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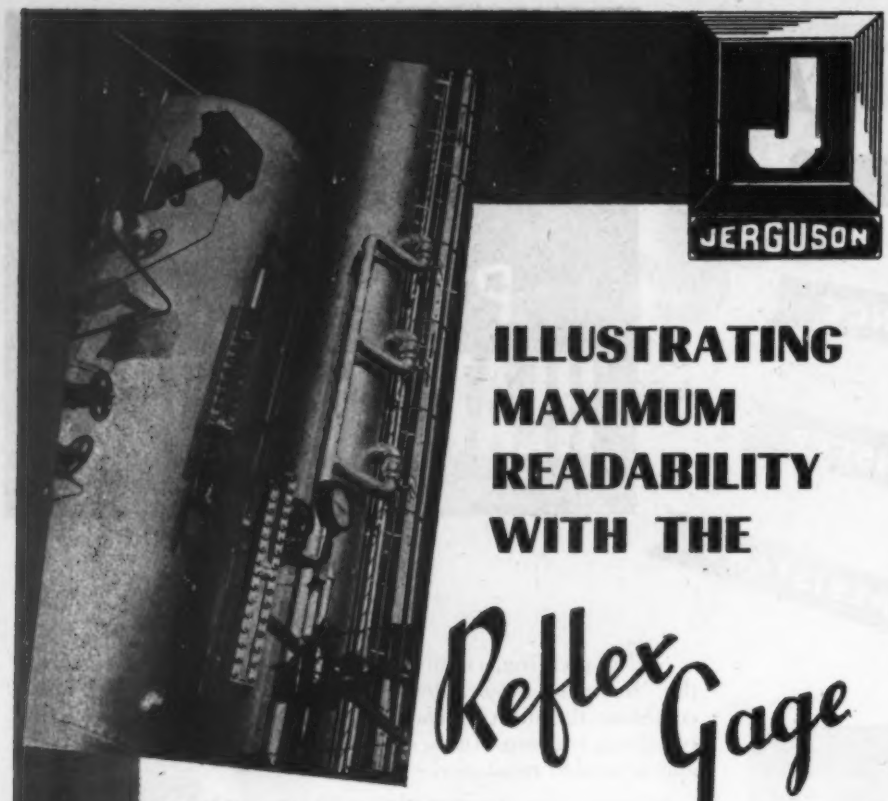

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are 450-700° C. and the active catalyst may consist of 10 percent Cr_2O_3-90 percent Al_2O_3.

HYDROGENATION DEHYDROGENATION AROMATIZATION

U.S.P. 2,403,879. Process of Manufacture of Aviation Gasoline Blending Stocks. W. A. Schulze and C. H. Helmers to Phillips Petroleum Company.

A hydrocarbon stream having a relatively high carbon-to-hydrogen ratio is aromatized at 1050-1250° F. in the presence of an alumina-base material. From the effluent three fractions are recovered, viz: 1. normally gaseous olefins, 2. a 200° F. end point normally liquid fraction, 3. a fraction boiling between 200-350° F. The second fraction is catalytically polymerized and a benzene fraction boiling between 160-180° F. recovered from the product. This fraction is catalytically alkylated with the first fraction. The third fraction is catalytically polymerized to reduce olefin and sulfur content.

U.S.P. 2,404,104. Method of Producing Ethyl Benzene. R. M. Shepardson to Standard Oil Development Company.

A petroleum fraction boiling between 260-275° F. and containing ethyl cyclohexane and xylenes but free from dimethyl cyclohexanes that boil below 260° F. is treated with a liquid solvent selective for aromatics, such as liquid SO_2, to remove the xylenes. The ethyl cyclohexane is then converted to ethyl benzene by dehydrogenation under elevated pressure at 600-1100° F. in the presence of a catalyst containing a metal, oxide or sulfide of metals of groups IV, V, VI and VII of the periodic system, and in the presence of added hydrogen. The ethyl benzene can be dehydrogenated to form styrene.

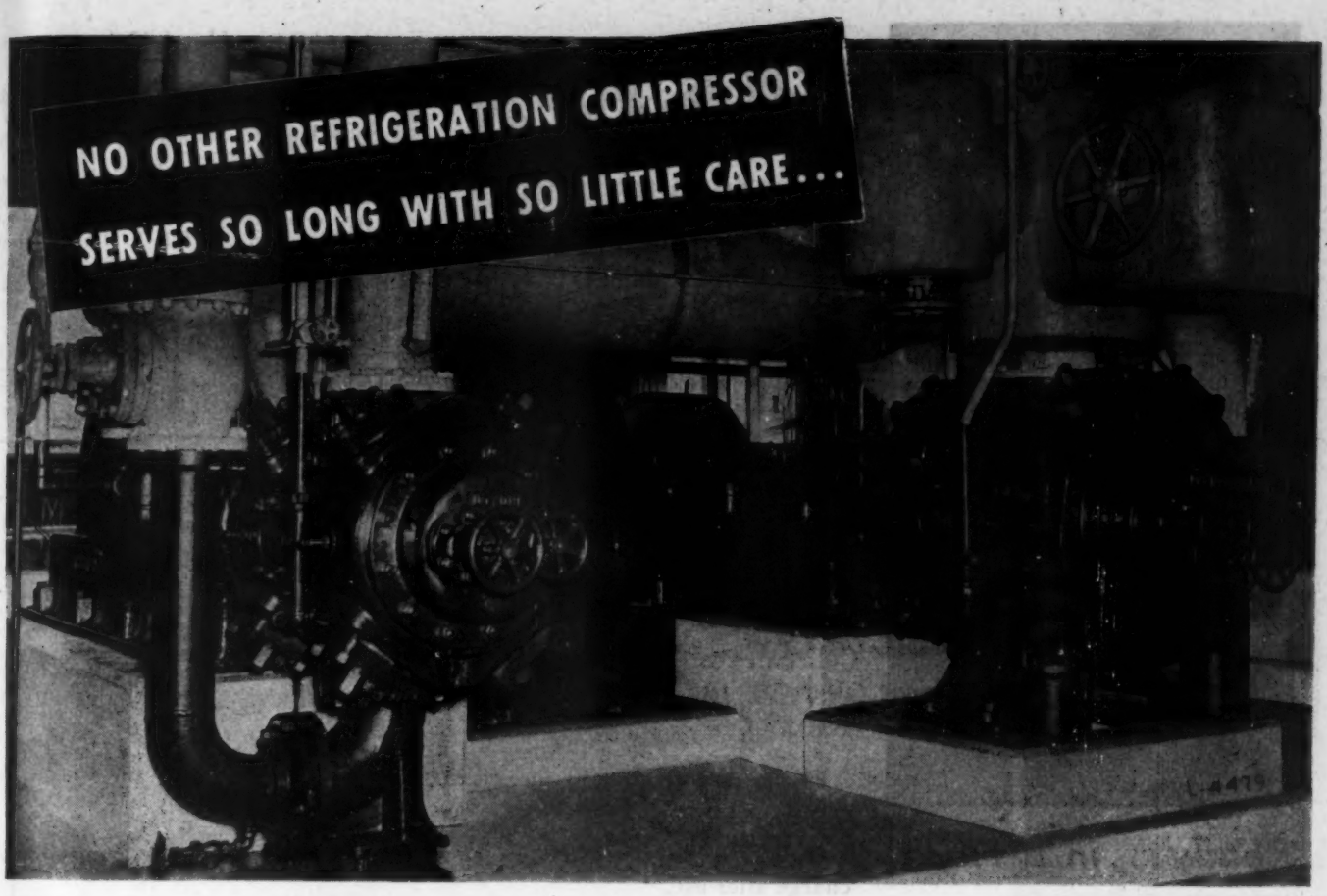
U.S.P. 2,404,902. Hydrocarbon Conversion. W. H. Claussen and T. M. Powell to California Research Corporation.

A narrow-boiling fraction (180-240° F.) from a paraffin-base petroleum is subjected to reforming, dehydrogenation and cyclization at 800-1050° F. and a pressure of about 15 psi in the presence of a chromic oxide-alumina catalyst in the presence of a hydrogen-containing carrier gas. The liquid product is cut to a fraction boiling substantially within the range of the original charge (227-232° F.) and this fraction is treated with a molybdena-alumina catalyst in the presence of carrier gas containing free hydrogen at 900-1025° F. and under about 200 psi pressure for a period of time sufficient to produce a product containing 90 percent aromatics. Toluene is recovered from this product.

CATALYST PREPARATION ACTIVATION AND REGENERATION

U.S.P. 2,403,753. Catalysts. J. A. Pierce and W. A. Spicer to Standard Oil Development Company.

A process for the activation of bentonite clays is described according to which the raw natural clay is treated for 30 minutes with 75 pounds (per 100 pounds of clay) of sulfuric acid having a concentration of 50 percent. The clay is then treated for about six hours with sulfuric acid of not more than 30 per-



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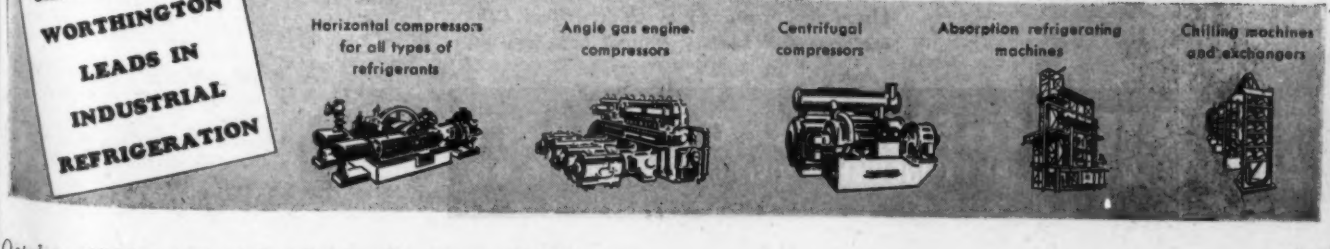
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cent and preferably of 12 percent concentration.

U.S.P. 2,404,024. Conversion Catalyst. J. C. Bailie, L. Heard and R. V. Shankland to Standard Oil Company (Indiana).

Vapors of petroleum naphtha and hydrogen are subjected to the action of an alumina catalyst at 800-1100° F. and a space velocity of 0.1-10. The catalyst is prepared from aluminum dross by treating it with acid until the gas evolution has ceased, precipitating, drying and igniting the resulting aluminum oxide. It contains about 2-20 percent of a Group VI metal oxide as a promoter which is introduced by addition of a salt of the metal before drying the alumina.

REFINING

U.S.P. 2,402,425. Extraction with Sulphur Dioxide. H. H. Meier to Standard Oil Development Company.

The extraction of cracked naphthas with SO_2 leads to operating difficulties such as coking of equipment. These can be avoided if care is taken to eliminate oxygen other than that combined with the SO_2 from the mixtures. This is done by stripping the naphtha in an operation in which oxygen is taken overhead and organic peroxides are rejected as bottoms. The fraction is then blanketed with an inert gas until it is mixed with the SO_2.

U.S.P. 2,403,673. Separation of Olefins. M. P. Matuszak to Phillips Petroleum Company.

Isobutylene is separated from butene-1 in a fractionation-isomerization column containing a solid isomerization catalyst, such as "black" chromium oxide magnesia or brucite. The column is operated at 150-250° F., effecting isomerization of butene-1 to butene 2 while not effecting isobutylene which is removed as overhead product.

U.S.P. 2,403,869. Aviation Gasoline Production. R. F. Marschner to Standard Oil Company (Indiana).

A hydrocarbon mixture containing propylene, n-butenes, isobutene, n-butane and isobutane is converted into aviation gasoline by first fractionally distilling the mixture to separate butene-2, then polymerizing the light fraction to a product containing much heptene (e.g. with a copper pyrophosphate catalyst), hydrogenating the heptene fraction, alkylating butene-2 with isobutane and mixing the alkylate with the hydrogenated heptene fraction.

U.S.P. 2,403,972. Process for Extracting an Aormatic Hydrocarbon from a Mixture Containing Other Hydrocarbons. B. S. Friedman to Universal Oil Products Company.

Aromatic hydrocarbons are extracted from their mixture with other hydrocarbons relatively free of olefins by means of a separating agent prepared by dissolving silver sulfate, oxide or carbonate in sulfuric acid and then reacting the solution with a hydrocarbon, such as benzene, to produce a mixture containing the silver compound, sulfuric acid and a sulfonic acid.

U.S.P. 2,404,094. Motor Fuels. A. E. Robertson to Standard Oil Development Company.

The invention relates to a motor fuel which comprises 80-98 percent of methanol and a minor proportion of an aliphatic or cycloaliphatic C_3 —C_5 hydro-

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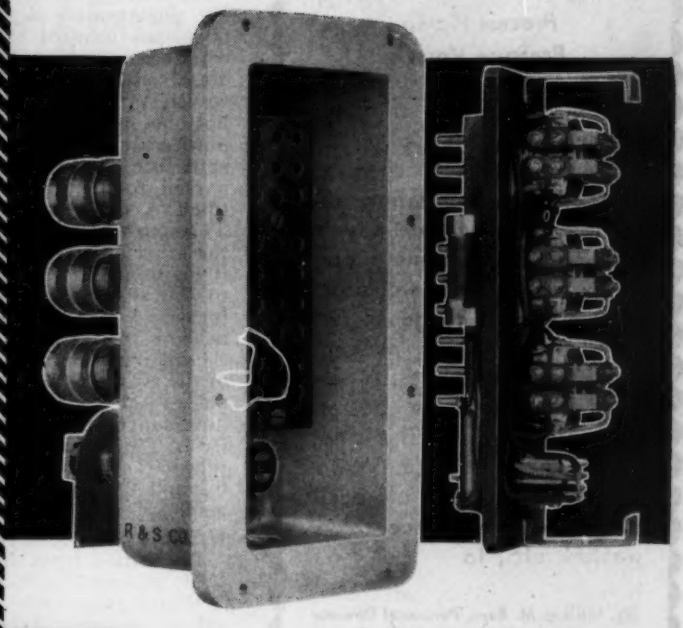

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carbon. The amount of hydrocarbon present shall be sufficient to raise the Reid vapor pressure of the blend to 5-13 psi at 100° F. A small amount of tetraethyl lead may be added.

U.S.P. 2,404,253. Extractive Distillation with Furfural. V. Scarth to Phillips Petroleum Company.

A mixed hydrocarbon stream containing unsaturated aliphatic hydrocarbons is passed upward through an absorber countercurrently to furfural containing dissolved water. Furfural rich in dissolved unsaturates is withdrawn as a bottoms product and stripped of these unsaturates. The stripped furfural is split into two streams, one of which is passed to a rerun unit and there distilled to regain furfural containing water. This purified furfural is combined with the other stream of stripped furfural and the combined furfural stream is recycled to the absorber. Polymerization of furfural and corrosion of equipment due to acid or to other factors is inhibited by the introduction of lime into that branch of the stripped furfural stream which bypasses the rerun unit. The amount of lime added is controlled so that the acidity of the furfural in the extractive distillation system is maintained between 0.2 and 0.6 percent calculated as acetic acid.

U.S.P. 2,404,405. Method for Removing Impurities from Mineral Oils. C. H. M. Roberts to Petrolite Corporation.

Water-dispersible impurities, such as saline material, are removed from mineral oil of low water content by first emulsifying the oil with small droplets of relatively fresh water. Then more fresh water is mixed into the mixture to produce an oil-continuous emulsion or dispersion. The mixing in both steps shall be controlled in such a manner that the droplets formed by the addition of water are of an average size different from those which are formed by the first addition so that the emulsion formed contains different sized droplets of water suspended in the oil. This emulsion is subjected to the action of an electric field to coalesce the water. The coalesced masses which contain the impurities to be removed are then separated from the oil.

U.S.P. 2,404,551. Treatment of Hydrocarbons. J. D. Upham to Phillips Petroleum Company.

A sludge or slurry from which it is desired to remove a free Friedel-Crafts type metal halide is contacted with a liquid substantially anhydrous hydrogen halide, which acts to dissolve metal halide from the inactive material. The metal halide is recovered from the solution by vaporization of the hydrogen halide.

U.S.P. 2,404,789. Apparatus for Fractional Distillation. R. E. Burk and E. Kropp to The Standard Oil Company (Ohio).

Contact apparatus arranged for upward gas flow and for drainage of liquid in film form is described which comprises a unit having multiple unobstructed narrow ascending vapor passways with walls providing smooth continuous free drainage of liquid film and formed of spirally wound radially spaced sheet material with attached continuous vertical spacing strips, such passways being open below to a space for input and open above to a space for off-take.

U.S.P. 2,404,854. Regeneration of Absorbent. J. W. Latchum, Jr. and J. S.

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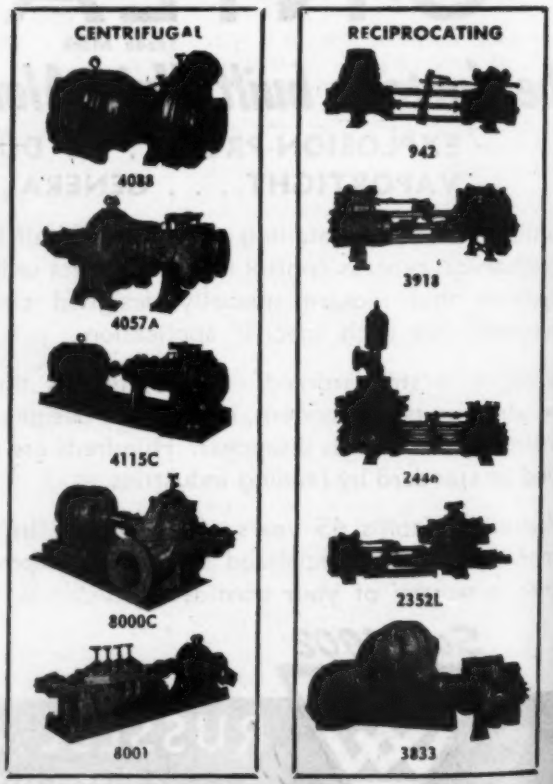

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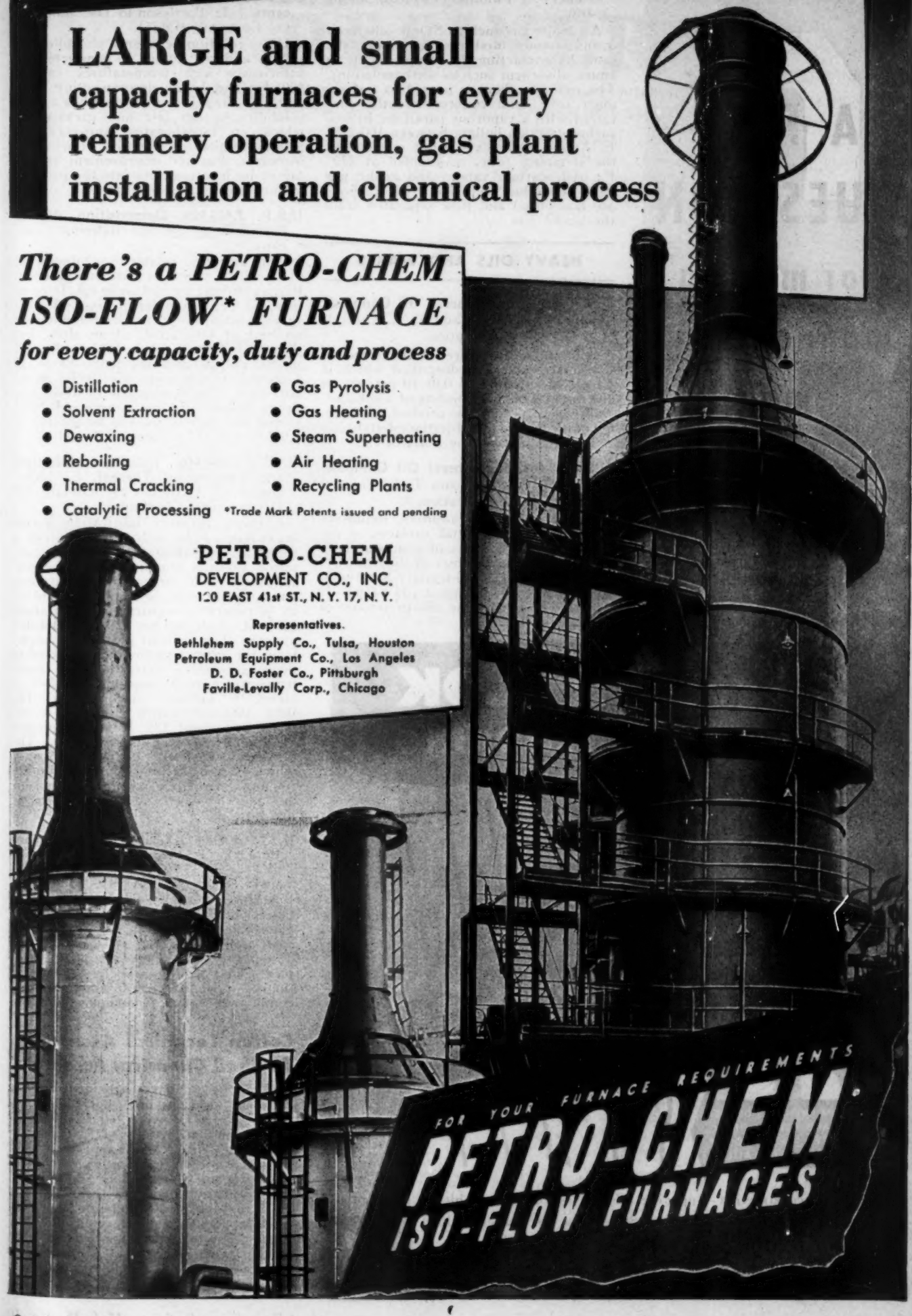

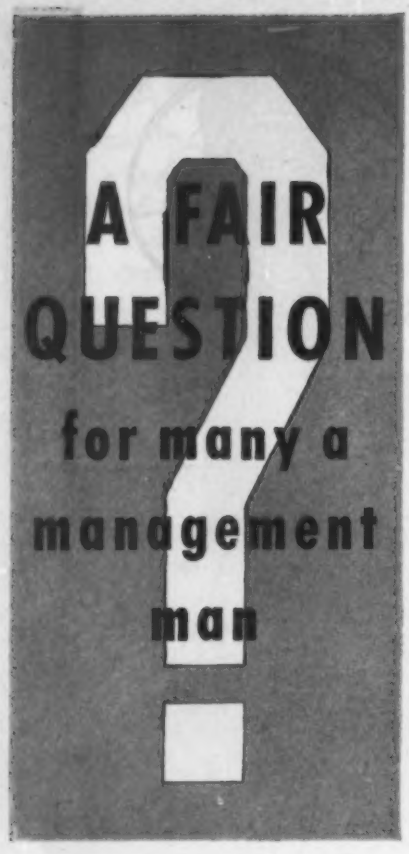

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Conners to Phillips Petroleum Company.

An acidic gas such as SO_2 is separated from gaseous mixtures containing the same by contacting the mixture with an amine absorbent such as diethanolamine. The rich absorbent is passed to a stripping zone and countercurrently contacted with a vaporous paraffinic hydrocarbon fraction boiling between 160-275° F. Amine is removed from one end of the stripping zone, maintained at 275° F., hydrocarbon vapors and acidic gas from the other end. The hydrocarbons are condensed and thus separated from the acidic gas.

HEAVY OILS AND WAXES

U.S.P. 2,403,764. Mineral Oil Composition. H. G. Smith and T. L. Cantrell to Gulf Oil Corporation.

A lub oil additive preventing corrosion of metal surfaces is described which is added in amounts of 0.01-10 percent to the mineral oil and consists of a substantially neutral addition product of dodecylamine and di-(2,4 ditertiary-butyl-phenyl) phosphate, having a pH of 7.2.

U.S.P. 2,403,765. Mineral Oil Composition. H. G. Smith and T. L. Cantrell to Gulf Oil Corporation.

A lubricating oil additive, inhibiting the corrosion of metal surfaces is described which consists of a substantially neutral addition product of dicyclohexyl amine and di-(2,4 di-tertiary-butyl-phenyl) phosphate, having a pH of 6.8 It is added to lubricating oils in amount of 0.01-10 percent.

U.S.P. 2,403,894. Additives for Lubricants. J. D. Bartleson to The Standard Oil Company (Ohio).

If the reaction between a phosphorous sulfide and an amine is conducted at sufficiently high temperatures (above 400° F.) and below decomposition temperature, the reaction product has a high solubility in lub oils and greases, to which it incorporates anti-corrosive properties and the viscosity of which it increases. Further improvement is obtained by incorporating into the product sulfur, selenium or tellurium.

U.S.P. 2,403,928. Composition. M. P. Kleinholz to Sinclair Refining Company.

This invention relates to a mineral oil composition which is particularly effective as turbine or hydraulic oil. It comprises a petroleum lubricating oil fraction containing a small compounded amount of semilactide of an alpha hydroxy aliphtaic acid in which the aliphatic radical contains from 10 to 18 C atoms. These acids effectively retard corrosion. The semilactide of alpha hydroxy lauric acid is a preferred compound and may be used in an amount of 0.0057 to 0.0115 percent of the oil.

U.S.P. 2,404,446. Lubricant Additives and Preparation Thereof. E. Lieber and A. F. Cashman to Standard Oil Development Company.

Extreme pressure lubricating agents are prepared by solvent extracting a chlorinated paraffin alkali polysulfide reaction product containing 5-10 percent sulfur and 30-40 percent chlorine at room temperature with isopropyl alcohol of ca. 91 percent concentration, using about 1000 ml. of alcohol per 1200 g. of treated material. The raffinate phase is separated from the extract phase and subjected to three successive extractions at room temperature with isopropyl alcohol of about 99 percent concentration. The thus obtained fourth raffinate is extracted at about 125° F. with isopropyl alcohol of 99 percent concentration. The pressure lubricant additive obtained which is free of low-sulfur constituents remains completely soluble during storage and shows an improved load-carrying capacity.

U.S.P. 2,404,871. Lubricating Compositions. P. R. Van Ess, F. J. Watson and G. M. Whitney to Shell Development Company.

A substantially paraffinic, sulfur-containing lub oil raffinate is extracted with glacial acetic acid saturated with mercuric acetate at about 50° C., producing a mercury salt-sulfur compound complex. The complex is broken to recover the components. The extracted sulfur compounds form corrosion inhibitors.

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Colten Technical Assistant To Shell Chemical President

O. A. Colten recently was named technical assistant in the president's office of Shell Development Company at San Francisco. After a B.S. degree in chemistry from Fort Wayne University he received his doctorate from Michigan in 1936, and immediately joined Shell Oil Company as a junior technologist at St. Louis. He was appointed technologist at Houston refinery in 1938 and advanced to senior technologist the following year. Since 1941 he has been in the research and development department, manufacturing, at New York.